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BURNED AND TRAUMATIZED HANDS

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MAJOR surgical conditions of the hands befalling soldiers are common and present a most serious problem. There are two main groups into which these problems may be classified: (1) burns and (2) trauma.

Burns and trauma of the hands are particularly important because of the loss of function which frequently follows these conditions. Burns and trauma to other parts of the body may often be considered as problems in healing and cosmetics, but rarely do they present problems in function as complex as the function of the hands. From the time that first aid is administered, function of the hands must be considered. Otherwise disaster is met.

BURNS

First degree burns and second degree burns, unless extremely extensive, are rarely serious problems. Burns involving all the layers of the skin and those involving skin and deeper structures are most serious. The so-called third degree burn will be especially considered.

The Army makes great effort to prevent burns by emphasizing the dangers associated with handling gasoline and other inflammable materials and by instituting suitable safety measures. However, in modern warfare, with flame throwers and high explosives, burns are inevitable.

Burns of the hand most often accompany burns of other parts of the body. In the early management of a burn casualty, the primary considerations are: (1) prevention and control of shock, (2) prevention of contamination of the surface of the burn during treatment and evacuation and (3) application of a sterile pressure dressing on the burn.

Initial Care.—In the initial care of the patient, pain is controlled by morphine. In extensive burns a ½ grain (30 mg.) dose of morphine may be necessary. In shock, anoxia may be present, and large doses of morphine are dangerous. In such circumstances the dose should not exceed ¼ grain (15 mg.). In shock, absorption of morphine given subcutaneously or intramuscularly may be delayed, in which case repeated doses of morphine should be given with caution. Relief of shock and improvement in peripheral circulation may lead to rapid absorption and overdosage if administration of morphine has been

repeated in such cases. Careful intravenous administration of morphine has the advantage that pain is more promptly and certainly controlled, and the danger of overdosage from repeated subcutaneous or intramuscular administration is nullified. A dosage of 1/6 to 1/4 grain (10 to 15 mg.) given slowly in 10 cc. of sterile water or isotonic solution of sodium chloride and repeated as necessary is perhaps the safest method of intravenous administration of morphine.

Early therapy for replacement of plasma is instituted. If evacuation cannot be carried out quickly to a place for definitive therapy, administration of plasma is started as part of the first aid measures. If 1 or 2 units of plasma are given early, even in the first half-hour, lives may be saved. Quantities of plasma up to 12 units may be required in the first twenty-four hours for extensive burns. If a patient is in shock when administration of plasma is started, the first 2 or 3 units should be given rapidly. The best laboratory methods for investigating the severity of shock are determination of the red blood cell count, hematocrit reading, specific gravity of the blood and hemoglobin content of the blood. These determinations govern the quantity of plasma to be given. Determinations of blood chloride, potassium and protein levels and carbon dioxide–combining power are of value.

From the first, efforts should be made to prevent contamination of the surface of the burn by organisms from the nose and throat. Persons handling a patient should always be masked. Aseptic technic with gloves and instruments, if possible, should be used at all times.

No cleansing or débridement is attempted in the field. This procedure is performed in hospitals, where complete facilities for definitive treatment are available. A fresh burn is covered with a sterile pressure dressing, and the patient is evacuated to a hospital for definitive treatment as quickly as possible. Boric acid ointment or petrolatum is not applied to a grossly contaminated burn, because they complicate the later cleansing of the burned surface. If a local application is considered necessary, 5 per cent sulfadiazine cream is preferred because of its bacteriostatic effect and its relative ease of removal later if cleansing and débridement are considered necessary. Sulfadiazine is rapidly absorbed from a burned site, and care must be exercised to prevent an excessive dose.

Severe burns of the hands or of one hand alone have been recognized by the Army as major burns, and the patients are evacuated to a hospital for definitive treatment. Administration of tetanus toxoid is indicated for all patients with second or third degree burns. With gross contamination, sulfadiazine therapy may be instituted in the field.

Definitive Care.—Phase 1. Control of Shock: Morphine controls the patient's pain. Shock is treated with plasma.

Phase 2. Operation and Control of Infection: Cleansing and débridement are performed oftenest with the patient under general anesthesia. Pentothal sodium is usually used. A brachial block is suitable in some cases. Gross dirt is removed by immersion of the patient's hand in a basin of sterile soap and water and swabbing the hand gently with sponges. Oil and grease are removed with ether. After cleansing, the hand is prepared and blebs are excised. Devitalized tissue is removed. A culture should always be taken of the bleb fluid or of the burned site.

Aldrich and Firor [1] have shown that beta hemolytic streptococci and gamma streptococci usually contaminate a burn, and culture of these organisms may be obtained within twenty-four hours. The first culture is tested for sensitivity to penicillin and sulfadiazine, and chemotherapy is begun in extensive burns before the result of the culture is reported. Repeated cultures may be taken.

Test for sensitivity to penicillin. A trench plate technic is used to determine the sensitivity of an organism to penicillin. A blood agar plate is used, and a trench 1 cm. wide is removed from the middle of the plate. The trench is filled with a mixture of agar and penicillin containing 1 unit of penicillin per cubic centimeter of the mixture. Care is taken to cool agar below 50 C. before the penicillin is added. The plate is streaked with the standard strain and with the organism to be tested. Inhibition of the standard strain averages about 8 to 10 mm. Insensitive strains occasionally grow across the penicillin-filled trench.

Freshly prepared plates must be used for each test; otherwise the penicillin diffuses throughout the plate.

Test for bacteriostatic power of patient's serum. An attempt is made to determine whether or not the patient is receiving enough penicillin by testing the patient's serum for a bacteriostatic level. A sample of the patient's blood is obtained and the serum separated, sterile technic being used. Four test tubes are set up containing the following contents: (1) undiluted serum, (2) serum diluted 1:2 with broth, (3) serum diluted 1:4 with broth and (4) broth without serum, for a control. If facilities permit, a more accurate estimation of the amount of penicillin in the blood serum can be obtained by making dilutions up to 1:32 or 1:64. Each tube is inoculated with a loopful of a diluted (1:1,000 or 1:10,000) twelve hour broth culture of the patient's organism. After twelve hours' incubation, the result may be determined either by inspection or by subculture on agar plate. The latter is more desirable. If the serum is bacteriostatic, the first tube should show no growth; frequently inhibition is noted in the second and third tubes as well. Repeating this procedure on samples drawn at hourly intervals

1. Aldrich, R. H.: New England J. Med. **208**:299, 1933.

between two successive doses gives an indication, first, as to whether the patient is receiving enough penicillin to produce bacteriostasis and, second, as to whether the bacteriostasis persists throughout the interval between doses.

Bacteriologic studies are made for aerobic and anaerobic organisms. A period of inadequate penicillin therapy may render a sensitive organism penicillin resistant. This is important in determination of penicillin dosage. For serious infections an initial intravenous dose of 20,000 units should be given. This should be followed by intramuscular doses of 10,000 to 20,000 units every two hours until the infection is under control or proved to be resistant to penicillin. Sulfadiazine is the sulfonamide drug of choice.

Test for sensitivity to sulfonamide drugs. A broth medium with 20 volumes per cent of a sulfonamide drug may be used, inoculated with the etiologic bacteria. Other broth mediums with 10 volumes per cent, 5 volumes per cent and 2½ volumes per cent of sulfonamide compounds may also be inoculated. If growth is inhibited with a broth medium containing 10 volumes per cent of a sulfonamide drug, the organism is sulfonamide sensitive. However, this sensitivity test is inaccurate because peptones in the broth inhibit action of sulfonamide compounds. The best indication for sensitivity of an organism to a sulfonamide drug is the clinical reaction of the infection to the drug. An initial dose of 4 Gm. of sulfadiazine is given and then 1 Gm. every four hours until signs of acute infection have subsided for forty-eight hours. This dosage gives adequate concentration in the blood to carry out bacteriostasis. Toxic reactions are minimal.

If a choice were to be made in chemotherapy, penicillin would probably be the drug of choice. The sensitivity of the organism to the drug can be more accurately tested with penicillin, and reactions to penicillin are fewer than those to sulfadiazine. However, with infections due to gram-negative bacilli sulfadiazine is indicated.

Phase 3. Specific Functional Therapy: A consideration of the function of the hand should be made with no less diligence than consideration of shock and infection. Grave errors have been made in the past because of the lack of proper attention to the function of the hand early in the treatment. In a third degree burn involving skin only, the prognosis as far as function is concerned is good. Prognosis becomes poorer as the burn penetrates deeper to include fascia, tendons, capsules of the joints and bones.

In many cases it is not possible to tell how much of the burned site is second degree and how much is third degree. Four days after receiving the burn is about as soon as one can clearly distinguish the degrees of the burn. With severe burns of the hand specific functional therapy is begun immediately after the débridement.

Changes in physiology and pathologic states of burns of the hands have been ignored too often in the past and have led to irreparable changes in the tissues. The sight of a burned hand which is edematous and indurated and has limited motion in every joint has been much too familiar in civilian practice. The fascial spaces, especially on the palm, are numerous, and accumulations of exudate and fibrosis in these spaces can lead to nothing but limited function.[2]

The present concept of the change in physiology in a burned hand [3] is that there are damaged capillaries in the burned area which permit the escape of plasma and some whole blood into the intercellular spaces. If there is a complicating burn over a large extent of the surface of the body there is a decreased volume of blood. The resultant impaired circulation with a decreased volume of blood leads to anoxemia throughout the entire body. This anoxemia damages capillaries everywhere, so that a dilatation and increased permeability of capillaries in all tissues exists. Specifically, as far as the burned hand is concerned, it means that there is a tremendous accumulation of plasma in the intercellular spaces. Fibrosis occurs as a phase in the response of tissue to injury.

Due consideration must be given to the prevention of the accumulation of exudate in the intercellular tissues, to the mobilization of fluid accumulation in these tissues and to the prevention of dangerous fibrosis.

Roulston [4] applied casts to burns of the extremities after maximum swelling occurred and infection was present. Zeno [5] used plaster casts in fresh burns and felt that the good results were due to the immobilization. Allen and Koch [6] advocated pressure dressings for burns. Glenn, Peterson and Drinker [7] showed that the application of a close-fitting cast immediately after the burn would prevent swelling, and at the same time the circulation in the burned extremity was unimpaired. However, impaired capillary flow occurred in the untreated extremity. These investigators reported that the benefits of the treatment decrease according to the amount of swelling that precedes the application of a cast. Levenson and Lund [8] have recently reported satisfactory results in 23 cases in which close-fitting plaster of paris casts had been used.

Barron [9] has suggested another method for the mobilization of the intracellular exudate, based on the theory of ionization. He applies a

2. Flynn, J. E.: Am. J. Surg. **55**:457, 1942.

3. Blalock, A.: Principles of Surgical Care: Shock and Other Problems, St. Louis, C. V. Mosby Company, 1940.

4. Roulston, T. J.: Brit. M. J. **2**:611, 1941.

5. Zeno, L.: Arch. urug. de med., cir. y especialid. **14**:322, 1939.

6. Allen, H. S., and Koch, S. L.: Surg., Gynec. & Obst. **74**:914, 1942.

7. Glenn, W. W. L.; Peterson, D. K., and Drinker, C. K.: Surgery **12**:685, 1942.

8. Levenson, S. M., and Lund, C. C.: Treatment of Burns of Extremities with Close Fitting Plaster of Paris Casts, J. A. M. A. **123**:272 (Oct. 2) 1943.

9. Barron, J.: Personal communication to the author.

sterile pressure dressing to the burned hand, the upper layer of which is soaked in isotonic solution of sodium chloride. A small rubber tube inserted into the dressing permits isotonic solution of sodium chloride to be inserted as needs be. The anode of a galvanic current is placed on the gauzes soaked in isotonic solution of sodium chloride. He reported excellent results by this method.

In the Army, a patient who is burned in the Combat Zone passes through many hospitals in the process of evacuation. Many different surgeons may treat a patient with burned hands. In such circumstances it would be impractical to apply a tight-fitting cast to the burned upper extremity. The hand is immobilized in a position of function on a molded anterior splint. A firm elastic bandage is then applied to obtain the desired pressure. In some cases it is undesirable to use a plaster splint. A firm elastic bandage applied over the dressing may be suitable.

Method. Most war burns must be débrided and cleansed because of contaminants. The serum from blebs is cultured. A layer of sterile petrolatum gauze is applied over the whole burned site. The petrolatum gauze is also placed between the fingers. Eight layers of mesh gauze are then fitted over the petrolatum gauze to permit absorption of surface fluid. The hand is then supported on a molded anterior splint, extending from a point 2 inches (5 cm.) above the burn to the tips of the fingers. The desired pressure is then obtained with an elastic bandage. The anterior splint is molded with the hand in a position of function, i. e., the wrist is dorsiflexed to about 35 degrees, the fingers are flexed approximately 40 degrees at all joints and the thumb is flexed about 15 degrees and rotated so that its volar aspect faces the volar aspect of the index finger.

All extensive burns are given chemotherapy. Static motion of flexor, extensor, adductor, abductor, lumbrical and interossei muscles is performed, while the hand is in the pressure dressing, fifteen minutes three times a day.

With hands which are grossly contaminated at the time of the burn, dressings must be changed daily. With hands which are relatively clean at the time of the burn, the pressure dressings are not changed for four days. The use of faradic current will give an idea of how much disability will eventually exist. If infection exists, local treatment will preserve some of the epithelial islands which may otherwise be destroyed. Over 50 per cent of burns are now in need of no more pressure dressing or cast. A small per cent need more pressure therapy. A smaller per cent are found eventually to cause partial or complete ankylosis of some joints. In the last group the patients may be given faradism or exercises to maintain whatever motion remains besides immobilization in a position of function.

The largest per cent of patients, who need no more pressure after four days, are now ready for a most important specific functional therapy, which consists in immersion of the burned hand in a sterile solution of warm isotonic solution of sodium chloride. Sterile water should not be used because, with much soaking, some of the cells in the epithelial islands undergo crenation. The hand is immersed in the fluid daily for one hour. Exercises for every joint in the hand and for all tendons and muscles beneath the burn are actively carried out in the bath, at five minute intervals, with the hand continuously in the bath. The exercises follow a definite pattern, with supervision by one who understands the complex mechanism of the hand. Flexion and extension of each phalanx are performed. Abduction and adduction of each finger are next performed. Opponens action of the thumb and little fingers follows. The most important exercise of all is flexion of all fingers at the metacarpophalangeal joints with extension of the fingers, i. e., exercises of the lumbrical and interossei muscles. A hand in which the function of the lumbrical and interossei muscles is maintained is a useful hand. After the bath the hand is dressed with sterile technic. The entire burned site is covered with sterile petrolatum gauze. Sterile gauze is applied over the petrolatum gauze, and the hand is again supported on the molded anterior splint. In two to three weeks, immobilization is no longer necessary.

Many errors have been made in the past in civilian practice. The outstanding errors have been a failure to apply the proper pressure in the early stages of the burned hand and immobilization of the hand in an improper position. The deformity after the hand has been immobilized in a position of extension has been too familiar in the past, with hyperextension of the metacarpophalangeal joint and some flexion of the proximal and distal interphalangeal joints. Flexion of the metacarpophalangeal joint can never be accomplished to a point of any functional value. The hand is not even a useful hook.

In some cases only one or two fingers may ultimately be ankylosed. It is important in such cases to place these fingers in a position of function; otherwise the other fingers, particularly the adjoining ones, will not completely flex. The reason is that the flexor profundus of a finger which is ankylosed in a position of extension cannot be drawn proximally through its full excursion by the common flexor profundus muscle. The common flexor profundus is held and cannot fully flex the adjoining fingers.

In the presence of a severe burn in the palm, there is usually a temporary loss of function of the lumbrical and interossei muscles. Prolonged immobilization of metacarpophalangeal joints in a position of extension in the presence of severe burns will lead to contracture of the collateral ligaments and cause limited flexion of the metacarpophalangeal joints.

Phase 4. Skin Grafting: Grafting of skin over the burned area must be performed as soon as the recipient site is suitable to receive the graft, to keep contractures at a minimum. Attempts at immediate grafting for the greatest part have been failures. About the earliest that an extensive third degree burn of the hand can be made suitable for grafting is after three weeks. Thiersch or split thickness grafts may be used.

A modification of the Sano coagulum-contact method [10] is of value when the area requiring grafting is irregular and promontories must be covered. Continuous pressure over such a site has always been a problem. Leukocytic suspensions with and without heparin have been used. The recipient area has been painted with the prepared plasma and the graft painted with leukocytic cream. In five minutes the graft is firmly adherent, and the danger of the graft's floating off has been removed.

It has been found that plasma twice as concentrated as that used to combat shock provides a suitable coagulum for the graft. A pressure dressing is applied with the hand in position of function for immobilization. The pressure dressing is removed in one week. Active motion is usually begun one week to ten days after grafting.

If the pateint has had an extensive body burn besides that on the hand, it is well to investigate his blood chemistry before grafting. Some failures in grafting have been reported when the serum protein levels are low. Especial consideration should be given to the blood protein and vitamin C contents before grafting. Deficiencies in serum protein and vitamin C are easily combated. Proper metabolism is a factor in resisting infection and is also needed for grafting to be successful.

TRAUMA

Trauma of the hands is considered especially from the viewpoint of wounds. The proper treatment of wounds is of paramount importance to the function of the hands. Early but not primary closure is the key to the problem. Wounds of the hands incurred in war present a different problem from wounds in civilian practice. The wounds are usually more mutilating, may be accompanied with other severe wounds and shock and are more frequently contaminated by tetanus bacilli, Clostridium welchii and other pyogens than wounds in civilian practice.

Initial Treatment.—General Consideration: Primary care of wounds is not concerned with débridement of wounds but is directed toward (*a*) prevention of infection, (*b*) control of hemorrhage, (*c*) relief of pain, (*d*) adequate immobilization and (*e*) prevention or treatment of shock.

(*a*) Prevention of Infection: An increase in contamination is prevented by masking the nose and mouth and by discouraging needless

10. Sano, M. E.: Surg., Gynec. & Obst. **77**:510, 1943.

probing or manipulation of the wound. Only superficial foreign bodies are removed. Antiseptics such as ether, alcohol or iodine are never introduced into the wound. A large sterile dressing, fixed securely, is applied to prevent further contamination during evacuation. Tetanus toxoid is given. The prophylactic treatment of tetanus has been one of the outstanding contributions of surgery in this war. Twenty thousand units of penicillin are usually given at a forward echelon, and administration of the drug is repeated along the line as needs be. Four grams of sulfadiazine, orally, is given early. One gram is then given every four hours. Chemotherapy is continued at all points in evacuation, even on hospital trains.

(*b*) Control of Hemorrhage: The hand is elevated, and an accurate and firmly applied pressure dressing controls most bleeding. Active arterial hemorrhage from a vessel which is visible in the wound may be checked by clamp and ligation. A patient is not evacuated until bleeding is controlled.

(*c*) Relief of Pain: In all cases adequate sedation is provided during examination, treatment and evacuation.

(*d*) Immobilization: All large wounds, even those without associated fractures, are immobilized during evacuation. The hand is supported on a molded anterior plaster splint with the hand and fingers in a position of function. The hand is kept elevated to prevent edema.

(*e*) Prevention or Treatment of Shock: Shock is combated by: (1) control of pain, (2) immobilization of the injured part and (3) administration of plasma (in general 1 or 2 units of plasma may be given to all patients with extensive wounds, regardless of the circulatory state). If there is a circulatory collapse, plasma and blood in amounts of 1,000 cc. or more are given. Patients in shock are not evacuated.

In a wound of the extremity, a note describing the presence or absence of paralysis or evidence of interference with the vascular supply of the extremity is made.

Definitive Treatment.—General Considerations: The extent of the injury is determined at once by an examination of motor functions and sensation of the hand. An estimate of the injury to tendons, muscles and nerves is made before the wound is inspected. An inspection of the wound is made. A culture of the wound is taken. Great care is taken to avoid further contamination by careless dressings or talking into the wound. Roentgenographic examination is done to localize foreign bodies preceding operation. Débridement of large wounds is delayed until shock has been adequately treated by plasma or whole blood. Unnecessary manipulation of the wound is avoided until operation is completed. Before the dressing is removed preliminary to débridement, the soiled skin is cleaned with soap and water.

The wound is protected from the cleansing agents with sterile gauze. All hair is removed from the margins of the wound by shaving. Nails are clipped and trimmed. Preoperative preparations of the skin are simple: soap and water scrub, followed by the application of ether, iodine and alcohol. Antiseptics are not introduced into the wound.

Débridement is always done under strict aseptic precautions, even when the wound is small. Multiple wounds due to small metallic foreign bodies do not require débridement. Simple cleansing with soap and water, frosting with sulfanilamide and application of a sterile dressing are adequate. Multiple small, superficially embedded foreign bodies are often best removed by scrubbing with a brush.

The wound is gently irrigated, sterile isotonic solution of sodium chloride being used. Irrigation is best accomplished by a gravity apparatus. The nozzle of the tube is placed into the deepest part of the wound, irrigation being done from within outward.

The extent of the underlying damage cannot be predicted from the appearance of the external wound. A small superficial wound may often lead into a larger wound of the deeper structures. In such cases incisions extending into the wound may be necessary to obtain adequate exposure. Such incisions are made in the long axis of the extremity. In the region of the joints the resultant scarring and possible contracture are decreased if the incision in the skin is made in the direction of the lines of cleavage of the skin transversely.

A small margin of skin is excised. It is rarely necessary to excise more than ⅛ inch (0.32 cm.) margin. All hemorrhagic and soiled subcutaneous tissue is excised. All readily accessible foreign bodies are removed; especially important are pieces of clothing and other nonmetallic materials. A prolonged search involving extensive exploration for relatively small foreign bodies is not indicated. Conservation is emphasized in removing fragments of bone. Only bone which is detached from the muscle, periosteum or a larger piece of visible bone is removed.

Repair of the tendons is not attempted except in the most ideal circumstances and these circumstances are most rare. After débridement, hemostasis and irrigation are complete, the wound is frosted lightly with sulfanilamide powder. No wound of the hand, regardless of the size, is closed primarily. However, an effort is made to cover delicate structures such as nerves, tendons and blood vessels with soft tissue. The wound is packed loosely. Tight packing is avoided. Drainage is afforded by gentle insertion of petrolatum gauze with ends protruding beyond the margins of the wound. The wound is covered with a large, sterile absorbent dressing, held in place by means of a firmly, but not tightly, applied bandage. In the postoperative management of

the wound, every effort is made to prevent secondary contamination by use of sterile technic and masking of the physician's nose and mouth while he is dressing the wound.

Treatment of Gas Gangrene: The most important factors in the prevention of gas gangrene are the thorough and complete débridement of devitalized muscle and the early replacement of blood. The most important factor in the treatment of established gas gangrene is early removal of all involved tissue. This frequently necessitates excision of entire muscle bellies or guillotine amputation. Chemotherapy is maintained. Administration of polyvalent gas gangrene antitoxin is of questionable value but may be used. Polyvalent gas gangrene antitoxin is administered, preferably intravenously, after suitable precautions against anaphylactic shock have been taken. An initial dose of 4 vials (26,000 units in each vial) is given intravenously. Additional injections of 3 or 4 vials every four to six hours for two to three days should be administered. Because of the fact that in gas bacillus infection there is rapid destruction of erythrocytes, transfusions of whole blood are used.

Specific Considerations: In the management of war wounds of the hand, the importance of early secondary closure or early skin grafting cannot be overemphasized. An early covering of a wound of the hand means less edema, less induration, less infection and less scar tissue with its accompanying contractures. Consideration for specific functional treatment of the hand is never more striking than in the early closure of war wounds. Closure of wounds of the hand takes precedence over therapy of lacerated tendons, injuries to the nerves and fractures.

The ideal time for closure of a wound by secondary suture or grafting has been a problem which experience has answered. The fourth or fifth day after débridement seems to be the earliest that such wounds should be closed. After débridement and cleansing, the wound is not dressed for four days unless a rise in temperature, a rapid pulse, pain and increased local heat are encountered, suggesting infection.

Technic of secondary closure may vary. If at the time of débridement and cleansing the wound appears clean, silk sutures may be placed in the wound and left untied. On the fourth day, with the patient under pentothal sodium anesthesia, the skin about the wound may be prepared with ether and alcohol and the sutures tied in place. This procedure provides a minimum of operative trauma and a minimum of anesthesia in a patient who may have previously been in shock and who may previously have had an extensive débridement and cleansing.

If the wound is grossly contaminated and dirty at the time of débridement and cleansing, no sutures are placed in the margins of

the skin. If there are no symptoms or signs of infection for four days, the dressing is removed on the operating floor and a culture is taken; if there is no gross evidence of sepsis, the edges of the skin are approximated without undercutting. If there is gross evidence of infection when the dressing is removed, a culture is taken, no closure is performed and the infection is treated by chemotherapy and local measures. The wound is inspected daily until all clinical evidence of infection has been quiescent for forty-eight hours. Despite lack of clinical

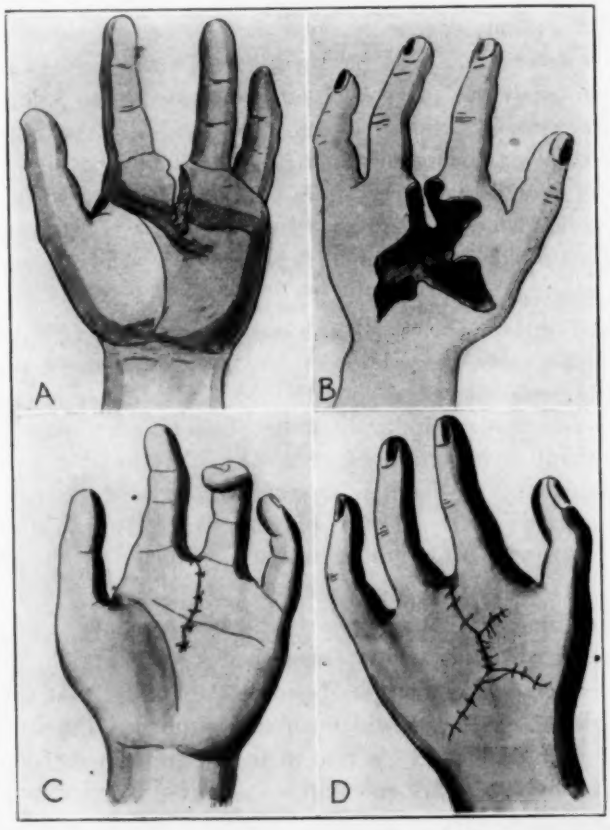

Fig. 1 (case 1).—*A*, anterior view preoperatively. *B*, posterior view preoperatively. *C*, anterior view postoperatively. *D*, posterior view postoperatively.

evidence of infection, a culture may show contaminating organisms in the wound. Despite the presence of these contaminating organisms the wounds are secondarily sutured loosely. About 90 per cent of the wounds can be closed on the fourth day.

CASE 1.—Case 1 is an example of a case in which a patient received an extensive wound of the hand which became septic; sepsis was controlled and secondary suture performed (fig. 1).

A rifleman was shot by a rifle bullet (30 mm.) in his left hand while in action with the enemy at about 1:45 p.m. on July 26, 1944 in Normandy, France. The wound of entry was on the palm and the wound of exit on the dorsum. The same day the patient was given first aid treatment at a battalion aid station. Sulfanilamide powder was dusted on the wound and a sterile dressing applied. Tetanus toxoid was given. The patient was then passed through a clearing station to an evacuation hospital. At about 7 p. m. on July 26, operation was performed at the evacuation hospital. A débridement of an extensive through and through wound of the hand was performed. The middle finger and the distal half of a shattered third metacarpal bone were removed. The wound was dusted with sulfanilamide powder, and petrolatum gauze was placed loosely in the wound. A plaster cast was applied with the hand in a position of function. The patient received a transfusion of 500 cc. of whole blood. Penicillin therapy, 20,000 units every three hours, and sulfadiazine, 1 Gm. every four hours, were given.

On July 29 the patient was evacuated by air to a holding general hospital in England. Administration of penicillin and sulfadiazine therapy were continued. On July 31 the patient was transferred by hospital train, in which penicillin and sulfadiazine were given, to a general hospital.

At a general hospital on July 31 a roentgenogram revealed an absence of the middle finger and the distal half of the third metacarpal on the left hand. The cast was removed. Examination of the left hand revealed that the third finger was absent. A wound which actually split the center of the hand was found. The wound over the distal half of the palm measured 2½ by 1 inches (6 by 2.5 cm.). The wound over the dorsum of the third metacarpal measured 3 by 2 inches (7.6 by 5 cm.). The wounds contained much slough and pus.

A culture taken from the wound on July 31 showed nonhemolytic Staphylococcus aureus, nonhemolytic streptococci and gram-positive anaerobic spore-forming rods (Cl. welchii). The organisms were sensitive to penicillin.

The patient was treated with penicillin until August 10. Hot chlorinated soaks were used four times a day, locally, through August 11. The hand was immobilized with a cast in a position of function. On August 10 there was no frank pus in the wound, and all slough had been excised.

A culture of material from the wound on August 10 revealed nonhemolytic Staph. aureus and gram-negative rods. Despite the culture, a secondary closure of the wound was performed on August 12 with the patient under pentothal sodium anesthesia. Edges of the skin were approximated without undercutting. Five sutures were taken in the palm, two sutures in the web between the index and ring fingers and sixteen sutures in the dorsum of the hand. Postoperatively, the hand was immobilized in a position of function. On August 19, seven days postoperatively, the cast was removed; all sutures were holding. Less edema and induration were found than preoperatively. One half of the sutures were removed on the seventh day postoperatively. The remaining one half of the sutures were removed on the ninth day postoperatively, and active motion of all fingers was begun. Two weeks postoperatively, all motions were within normal range.

All wounds of the hands cannot be closed by secondary sutures. Grafting may be necessary. Early grafting cannot be performed with burns of the hands, but early grafting must be performed on traumatic wounds of the hands. The same general principles hold for grafting in a hand that have been stated for secondary suture of the wounds. The earliest feasible time is four to five days following débridement. If the

wound is clinically clean four days after débridement, a split thickness graft may be applied. If tendons, nerves, blood vessels and bones are exposed, split thickness grafts will not take in those regions. A full thickness pedicle graft is then indicated. Full thickness grafts are preferable for defects of the palm.

If the wound is found septic, four days after débridement chemotherapy and local treatment in the form of hot soaks are given. When sepsis is controlled and the wound is grossly clean for forty-eight hours, grafting may be done. However, the results of the culture are a factor in determining the treatment. If there is no growth, a split thickness graft in the form of the defect may be applied.

If the culture reveals the presence of pathogens, "postage stamp" grafts may be applied. A "postage stamp" graft is a split thickness graft. This graft may be removed from the donor site by a Paget dermatome or by a free hand cutting. The split thickness graft is then placed with its external surface on a strip of petrolatum gauze. Grafts about 1½ inches (3.5 cm.) square are cut. Concentrated plasma, as an adhesive coagulum, is placed on the under surface of the graft. The square of graft and petrolatum gauze are then placed on the recipient site. A space of about 1 inch may be left between the grafts. It is wise to use some form of pressure over these grafts. The coagulum helps to retain the graft on the recipient site. However, serum is found in the spaces between the grafts, and this could be a factor in loosening the graft. Sterile petrolatum strips are placed over the entire wound after grafting, sterile gauze is then applied and sterile cotton wastē is applied over the gauze. Pressure is obtained by four sutures which are placed in the edges of the skin and tied firmly over the cotton waste in crucial fashion.

CASE 2.—Case 2 is an example of a case in which a patient received an extensive wound of the hand which became septic. After sepsis was controlled and appeared grossly clean, a culture showed contaminating organisms. "Postage stamp" grafts were applied (fig. 2).

The patient received injuries to his left hand, right thumb, both eyes and face as a result of fragments from an enemy 88 mm. shell which exploded in combat at about 9 p. m. on July 27, 1944, near St. Lo, France. Present consideration will be mainly of the wound to his left hand. Shortly after the injury the patient received first aid treatment at a battalion aid station. Sulfanilamide powder was dusted on the wound of his left hand and a sterile dressing applied. Tetanus toxoid was given.

The patient was transferred to a field hospital, where operation was performed at about 12 p. m. on July 27. At this hospital a roentgenogram revealed an absence of the index finger and middle finger, which had been blown off; a dislocation of the thumb at the metacarpophalangeal joint, with a severely comminuted fracture of both phalanges of the thumb; comminuted fractures of the greater and lesser multiangular bones; complete absence of the second and third metacarpal bones, which had been blown off; comminuted fractures of the fourth

and fifth metacarpal bones, and a severely comminuted fracture of the proximal phalanx of the ring finger.

The wound, on examination, was dirty and ragged. The thumb was attached by a small tab of skin. The index and middle fingers were absent. The second and third metacarpal bones were absent. There was some function by the flexor and extensor muscles to the ring and little fingers.

At the field hospital a débridement and irrigation of the wound were performed. The left thumb, which was avascular, was amputated. Sulfanilamide

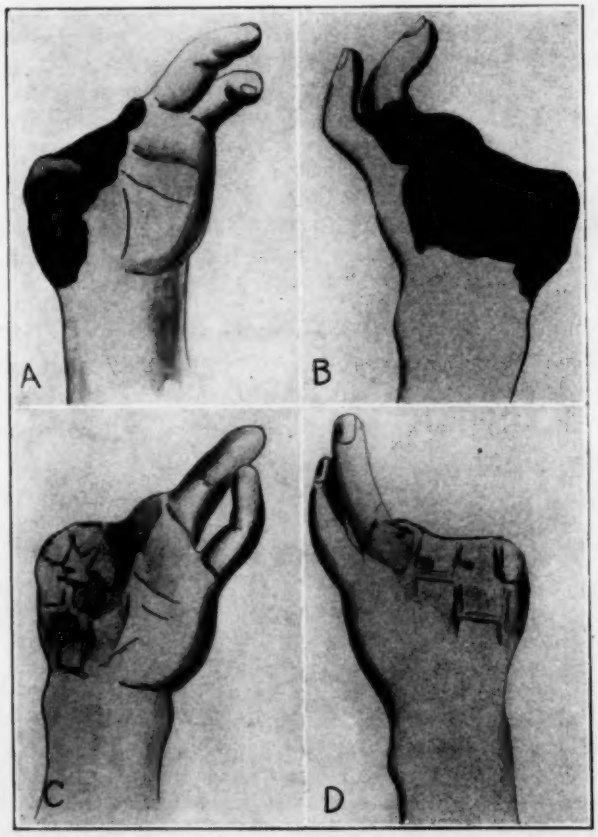

Fig. 2 (case 2).—Anterior (*A*) and posterior (*B*) views preoperatively. Anterior (*C*) and posterior (*D*) views postoperatively.

was dusted on the wound and a cast applied. Therapy with intramuscular administration of penicillin and oral use of sulfadiazine was given. Transfusions of whole blood were given.

Two days after injury, July 29, the patient was evacuated by air to a holding general hospital in England, where sulfadiazine and penicillin therapy was continued.

On July 31, the patient was transferred to a general hospital. A roentgenogram was taken. The cast was removed, and the wound was inspected. Examination revealed an extensive avulsed wound. The thumb and index and middle

fingers on the left hand were absent. The wound measured 4 by 3 inches (10 by 7.6 cm.) over the palm and 5 by 3 inches (12.7 by 7.6 cm.) over the dorsum. The wound was grossly septic and contained slough. No attempt was made at early closure. Material for culture was taken. Culture revealed anaerobic gram-negative rods (Cl. welchii), nonhemolytic streptococci, hemolytic Staph. aureus and aerobic gram-negative rods.

Penicillin and sulfadiazine therapy and hot soaks were continued until August 8. On this date the wound appeared grossly clean. The head of the first metacarpal bone and the devitalized ends of a few tendons were exposed in the wound. A culture of material from the wound made on August 8 revealed anaerobic gram-negative rods (Cl. welchii), nonhemolytic streptococci and hemolytic and nonhemolytic Staph. aureus. Despite this culture, "postage stamp," split thickness grafts were applied on August 10 and a cast applied. Seven days postoperatively, Aug. 17, 1944, the grafts were inspected and complete takes were found. Ten days postoperatively the cast was discarded and active motion begun. Two weeks postoperatively there was normal motion of the little finger and flexion was three-fourths normal in the ring finger.

This patient had an enucleation of his left eye on August 21 for an eye with lacerations of the cornea, in which the pupil was not visible, and with hemorrhage in the anterior chamber.

Many wounds of the hand are suitable for a combination of secondary suture and skin grafting. As much of the hand as possible should be closed by secondary suture provided that the resultant scar will not lead to a contracting deformity. Early closure of the wound is again stressed when this combination is used.

Case 3.—Case 3 is an example of a case in which a combination of secondary closure and skin grafting were used (fig. 3).

An infantryman was shot in the base of his right thumb by a fragment from an 88 mm. shell at about 1:30 a. m. on July 28, 1944, near Pierre in Normandy, France. First aid consisting in dusting the wound with sulfanilamide powder and application of a sterile dressing, and injection of tetanus toxoid was administered at a battalion aid station. Almost five hours after injury, the patient was operated on at an evacuation hospital. A roentgenogram revealed a fracture of the first metacarpal bone with a wide dispersion of fragments. The proximal one fourth of the first metacarpal bone was all that was intact. The distal three fourths of the bone was blown away. Three small fragments of bone remained where the distal three fourths of this bone should have been found. At the evacuation hospital a débridement and cleansing of the wound were performed. Penicillin and sulfadiazine therapy was instituted. A cast was applied with the thumb in a position of function. On July 29, 1944, the patient was evacuated by air to a holding general hospital in England. On July 31 the patient was admitted to a general hospital.

On August 1 a roentgenogram was taken, the cast removed and the wound inspected. There was no motor function of the thumb. There was some sensation over the dorsal aspect of the thumb. An extensive wound was found at the base of the thumb. The wound extended from the dorsal aspect of the thumb over the lateral and volar aspects to the dorsomedial aspect. The wound measured 4½ inches (11 cm.) in length. The muscles and tendons which were cut included both flexors, both abductors, both extensors, the opponens and the adductor pollicis. The thumb dangled by skin and fascia over the dorsum. However, the circulation appeared adequate.

The wound contained slough and pus. No closure was attempted. A culture revealed nonhemolytic Staph. aureus, nonhemolytic streptococci, Cl. welchii in small numbers and aerobic gram-positive rods. Administration of penicillin and sulfadiazine and hot chlorinated soaks were continued through August 20, when the wound appeared clean.

A culture made August 20 revealed hemolytic and nonhemolytic Staph. aureus, gram-negative rods of the coliform groups and Cl. welchii in small numbers. Despite this culture, a secondary closure was performed on August 22. Five silk sutures were placed over the dorsal and lateral aspects of the thumb. A split thickness graft was placed in the wide defect over the volar aspect. A

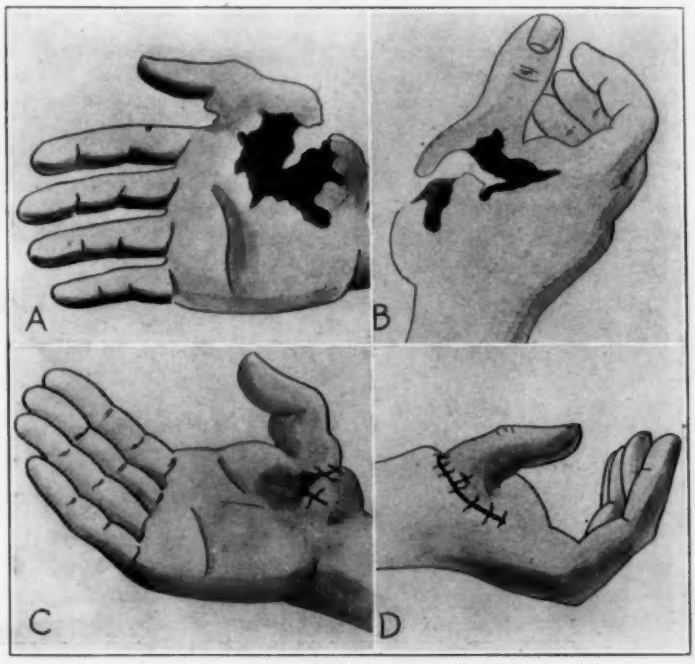

Fig. 3 (case 3).—*A*, anterior view preoperatively. The thumb is adducted to accentuate the defect. *B*, posterior view preoperatively. *C*, anterior view postoperatively. *D*, posterior view postoperatively.

plaster cast was applied. On August 29, one week after the operation, the cast was removed. The graft had completely taken, and the sutured area was healing. A plaster cast for the thumb only, immobilized in a position of function, was used for many weeks.

This case represented one in which amputation of the thumb may have been justified. However, if it had been performed the patient would have only a hook for a hand, and 50 per cent function of his right hand would be lost. Enough callus may form about the fragments of the first metacarpal, so that stable ankylosis with the thumb in a position of function may be obtained. With ankylosis of the thumb

in a position of function a useful physiologic forceps will be had as far as his right hand is concerned.

Pedicle grafts may be used for extensive wounds of the hand which are clean four days after débridement, especially in cases in which bones and tendons are exposed or in patients who have had a minimal infection which is quickly controlled. A full thickness graft is especially indicated for the part of the hand which will be exposed to work and trauma, i. e., the palm.

CASE 4.—Case 4 is an example of a case in which a patient had a minimum of infection and slough, in which case a pedicle graft was used (fig. 4).

Fig. 4 (case 4).—Preoperative (*A*) and postoperative (*B*) views.

The patient, 22 years of age, received wounds of his right wrist, right hand, left hand and right thigh from flak of an exploded shell while serving as a bombardier in a B-17 on an operational mission over enemy territory at about 10:30 a. m. on January 5, 1944. About three hours after being wounded, débridement, cleansing and sulfadiazine therapy were given at a station hospital. The right hand received the severest injury, and this will be the only injury considered. He was treated for sixteen days at the station hospital and transferred to a general hospital on Jan. 21, 1944.

A roentgenogram of the right hand and wrist showed fractures of the capitate and hamate bones and the proximal end of the fourth metacarpal. There were a fracture and partial absence of the triquetrum and the proximal half of the fifth metacarpal bone. Soft tissues showed multiple opaque foreign bodies.

The wound was inspected, and a slight amount of slough and pus was found A granulating mass was found to involve the medial one half of the palm and

wrist and extended around to the dorsal region of the fifth metacarpal bone. The granulating area measured 5 by 4 inches (12.7 by 10 cm.). The ulnar nerve was apparently destroyed at the time of the injury, because the patient had no sensation over the distribution of the ulnar nerve. He was also unable to abduct and adduct the index, middle, ring and little fingers. There was no function of the flexor digitorum sublimis or profundus tendons or of the lumbrical muscle of the little finger.

A culture of material from the wound revealed hemolytic and nonhemolytic Staph. aureus, nonhemolytic streptococci and aerobic gram-negative rods. Sulfadiazine therapy was continued. The patient also received hot soaks. Active motion of the fingers was begun. On February 12 the wound was free of slough and pus. A culture on February 12 revealed hemolytic and nonhemolytic Staph. aureus and nonhemolytic streptococci. Despite the culture, on February 14 a full thickness pedicle graft was freed from the abdomen and sutured to the granulating surface of the hand. On February 24 the graft was found to have completely taken and was cut free from the the abdomen. The defect on the abdomen was closed by suturing and split thickness graft. On February 26 physical therapy and active motion were begun.

The little finger was later amputated because of lack of sensation and loss of all motion due to injury of the tendons. By June 1, 1944, flexion and extension of the wrist were one-half normal. Adduction of the wrist was one-fourth normal. Motions of thumb and index finger were normal. Flexion of the middle and ring fingers was three-fourths normal.

This paper will not consider the problem of nerve suture, secondary sutures of the tendons, tendon transplant and the treatment of fracture, because these follow the course which has been well devised in civilian practice.

SUMMARY

One of the most important surgical advances in this war is the fact that war wounds have been early and safely healed after secondary closure or skin grafting. It is basically sound to leave war wounds open after the initial débridement, and this principle has saved many hands, limbs and lives by preventing sepsis. It is not basically sound to leave wounds open indefinitely after the danger from sepsis has passed. Early closure of wounds caused by burns or trauma eliminates pathologic processes that result in dense scar formation, ischemia, sloughed tendons and bones and loss of function.

Success of early closure of burns and traumatic wounds is due to the good condition of the patient and the good condition of wounds at the time the patient reaches the general hospital. Penicillin and sulfonamide drugs are important factors in controlling infections. However, other factors of equal importance to chemotherapy in obtaining good functioning results in wounds of the hand are early and adequate débridement and cleansing, control of shock and hypoproteinemia, the maintenance of a good nutritional state, judgment in closing wounds and the institution of early motion in the involved hand. About 90 per cent of traumatic wounds may be closed four days after débride-

ment. With traumatic wounds, moderate pressure with cotton waste and immobilization in a plaster cast help hemostasis, control edema and permit active motion in seven to ten days after closure.

The application of a pressure dressing to the burned hand as early as possible helps to prevent the accumulation of exudate in tissue spaces. In four days, the dressing is removed and most of the patients may be started on active motion of the hand in a bath of isotonic solution of sodium chloride. Three weeks is about the shortest period after which grafts can be applied to severe thermal burns of the hands.

If ankylosis is inevitable with deep burns or severe wounds of the hand, immobilization of the involved part in a position of function is maintained.

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MANAGEMENT OF COLOSTOMIES IN THE FIFTEENTH HOSPITAL CENTER (ENGLAND)

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DURING World War II any general hospital in the Communications Zone received in the course of time a fairly large number of patients with colostomies, performed one to three weeks earlier in the forward area hospitals, in association with wounds of the large bowel. It was therefore important to understand the problems involved, since these patients, in most instances, had to have their colostomies closed before return either to duty or to the Zone of the Interior, depending on a number of factors.

It was especially and understandably true during the earlier days of the invasion of the continent that the records returning with patients were at times either inadequate or nonexistent, so that occasionally there was no description of the procedure carried out or of the lesion for which it was performed. Thus the planning of the closure was made considerably more difficult.

One should remember that the picture was further complicated in possibly 50 per cent of the cases by associated injuries, especially to the thorax, small intestine, urinary bladder, urethra, ureter, presacral and sciatic nerves and by compound fractures of the pelvic bones.

The object of colostomy for a wound is (1) to divert the fecal stream from an extraperitoneal rectal wound, (2) to permit the exteriorization of mobilizable injured intraperitoneal colon or (3) to act as a proximal colostomy for protection of a suture line in a segment of nonexteriorizable intraperitoneal colon.

The types of colostomies commonly encountered are two, the first being the double-barreled Mikulicz variety, for extraperitoneal rectal wounds and for injuries in which there is a considerable amount of damage to the bowel, requiring exteriorization and sacrifice of a segment. Associated with the former injury one should institute adequate posterior drainage, preferably by excision of the coccyx and split of the

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Dr. Bartlett held the rank of lieutenant colonel, Medical Corps, Army of the United States, acting as consultant in general surgery for the Fifteenth Hospital Center.

fascia propria. The second is the loop type of colostomy, for exteriorization of a simple perforation or to act as a proximal colostomy for a nonmobilizable injured segment.

The foregoing procedures are essentially as directed by the office of the chief surgeon. In private practice one would be apt to modify some of these methods, which, however, have been shown to pay big dividends in cases in which many factors are concerned, such as occasional uncertainty as to the exact duration of the injury, the varying severity of the wounds of the bowel and, finally, the difference in individual judgment and experiences of a large number of surgeons working on war casualties.

The largest group of colostomies seen were located in the sigmoid, probably because of the high incidence of wounds of the buttocks with rectal perforation. It is my opinion that such a colostomy brought out through a McBurney type of incision on the left side is more satisfactory than that brought out through the left rectus or midline exploratory incision, principally because in the former instance the main incision is more apt to heal without infection and consequently the incidence of postoperative hernia is less common. It must be borne in mind, however, that the muscle-splitting and stab wound type of incision must not be too snug about the colostomy, for in such a case much edema of the bowel ensues and, in addition, obstructive symptoms may result. When a double-barreled colostomy is employed, the limbs should be approximated for a distance of about 4 inches (10 cm.) and care taken that the blood supply lies medial to the spur.

When the crushing of the spur preliminary to the closure of a Mikulicz colostomy is contemplated, a moderate amount of edema is no longer regarded as a contraindication to the procedure. It can usually be started about two weeks after the original colostomy by the application of two Ochsner clamps side by side. In between forty-eight and seventy-two hours a cut may be made between the clamps up to their tips rather than waiting for them to slough through, thus saving time. A second and occasionally a third application of clamps is invariably necessary a few days later in order to complete the obliteration of the septum. My colleagues and I have employed routinely a small amount of pentothal sodium intravenously when placing the clamps in order to avoid undue pain to the patient, for this is a different procedure from the application of the regular spur clamp for slow steady crushing, as in civilian practice. The latter instrument was not available in the European Theater of Operations.

In general, one must wait about ten days following the final obliteration of the spur in order to permit the resultant edema to disappear and to assure firm adherence of the limbs of bowel adjacent to the site of crushing.

The possible complications of spur crushing are injury to the blood supply of the limbs of bowel if not properly approximated at the original operation so as to assure the blood vessels lying medial to the septum, hemorrhage from the spur, injury to a loop of adherent small bowel and, finally, perforation of the peritoneal cavity by application of clamps past the lowest point of adherence of the limbs.

During the preoperative period of colostomy closure roentgenograms of the chest and abdomen were made with particular reference to

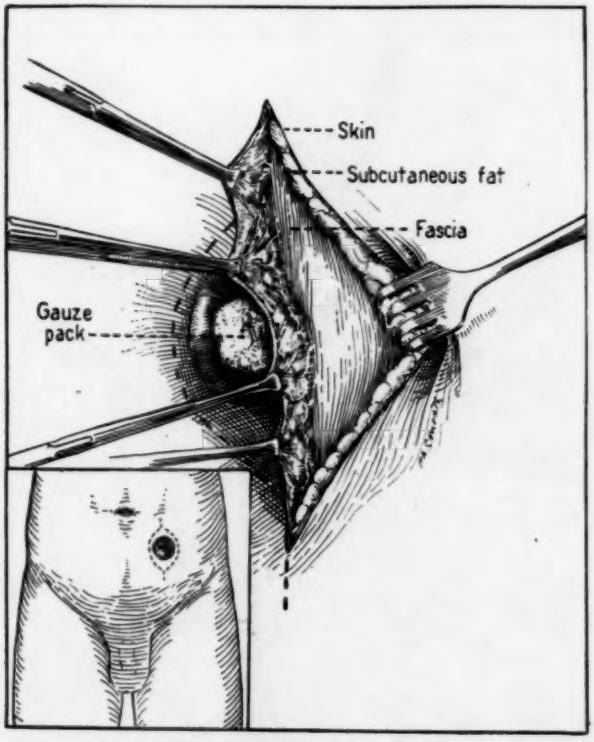

Fig. 1.—Circumcision of the colostomy opening.

foreign bodies and fractures, since, as stated earlier, so many of these conditions were complicated by multiple lesions. Compound fractures of pelvic bones with osteomyelitis and purulent drainage in the neighborhood of a colostomy are an absolute contraindication to repair, as failure will result due to infection in the wound. Then, too, in cases in which a suprapubic cystotomy and colostomy exist in close proximity to one another the wound in the bladder should be permitted to heal before closure of the colostomy is carried out, in order to avoid continual soaking of the wound with urine.

Also during this period of evaluation and preparation these patients were maintained on high protein, high caloric diets with multivitamins added and full correction of any existing anemia or hypoproteinemia made. In addition, barium enemas and proctoscopic examinations were performed, especially in cases in which there had been a rectal wound. Thus it was possible to be certain that a perforation no longer existed at the time of repair. Finally, when the edema was out of the colostomy and the wound was free of active infection, the last steps were taken in the preparation for closure.

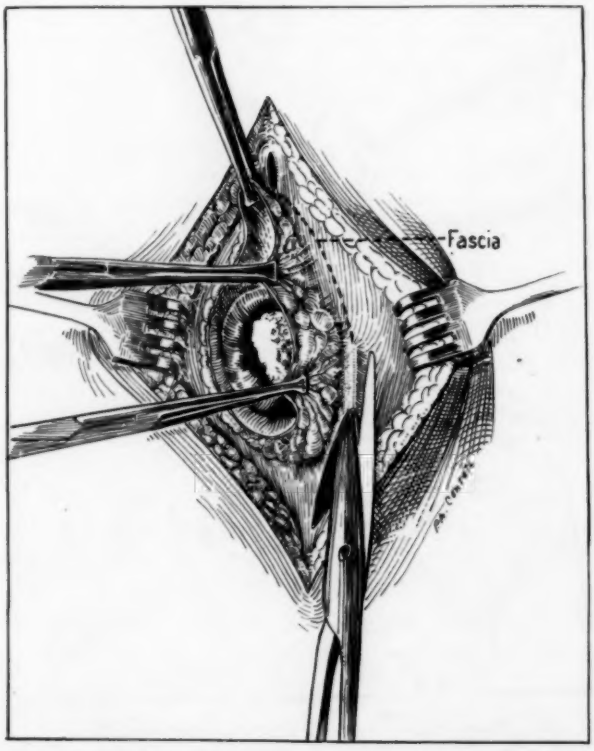

Fig. 2.—Incision and separation of the fascia and bowel.

As part of the immediate preoperative preparation the patient was placed on a nonresidue diet for three to four days and mild catharsis instituted; also, frequent irrigations of both colostomy loops were carried out. Chemotherapy was not employed routinely; however, in the light of present knowledge succinylsulfathiazole should be administered for practically all surgical treatment of the colon because of its proved ability to lower decidedly the bacterial count. Frequent doses of camphorated tincture of opium were given during the final twenty-four

hours and a digital rectal examination made for a possible fecal impaction which might act as an obstructive factor postoperatively.

In the case of sigmoid colostomies we found it useful to permit a button with a string attached to pass down the distal loop a day or two before operation, following which the string was fished out through the anus for subsequent use.

TECHNIC OF CLOSURE

Spinal anesthesia with a combination of procaine hydrochloride and tetracaine hydrochloride was employed routinely, and after its administra-

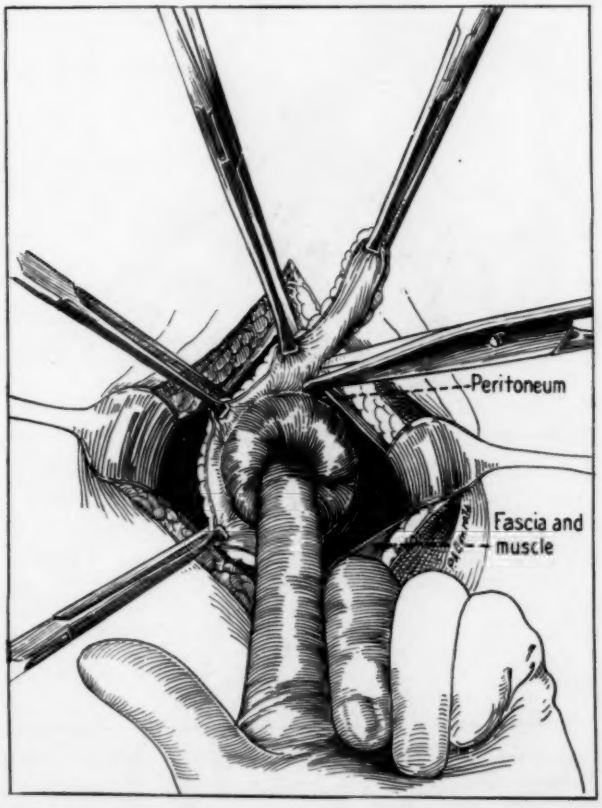

Fig. 3.—Skin and fat are trimmed from the bowel after mobilization down to the peritoneum.

tion a 3/16 inch (0.48 cm.) fenestrated flexible latex tube was fastened to the aforementioned string and passed up the rectum to just below the site of the colostomy if we happened to be dealing with one located in the sigmoid. A clamp was then fastened to the string about 6 inches (15 cm.) from the opening in the bowel and the excess string cut away.

After suitable preparation of the skin the colostomy opening was circumcised, a narrow margin of skin being left attached to the bowel to provide points of counteraction for the dissection and also to avoid direct trauma to the margin of the bowel. When the fascia is reached, this structure should be incised for a distance of 1 inch (2.5 cm.) both above and below the bowel, thus greatly facilitating the separation of fascia and muscle from the lateral and medial aspects of the colostomy. It was our custom to mobilize down to the peritoneum, which was not opened except occasionally as occurs unintentionally.

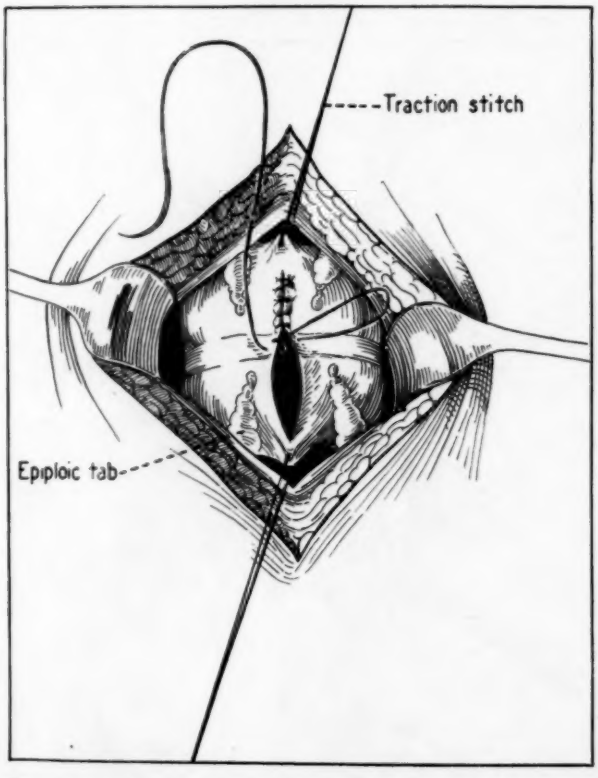

Fig. 4.—Transverse closure. The first row is done with a Connell continuous surgical gut mattress suture.

The margin of skin was then trimmed off, and, in the event we were dealing with a sigmoid colostomy, the small flexible rectal tube was threaded up the bowel 6 inches past the site of operation in order to act as a safety valve postoperatively. Transverse closure so as not to narrow the lumen was then carried out, a continuous Connell intestinal surgical gut suture being employed for the first row, followed by a row of interrupted fine silk mattress stitches. Epiploic fat tabs, if

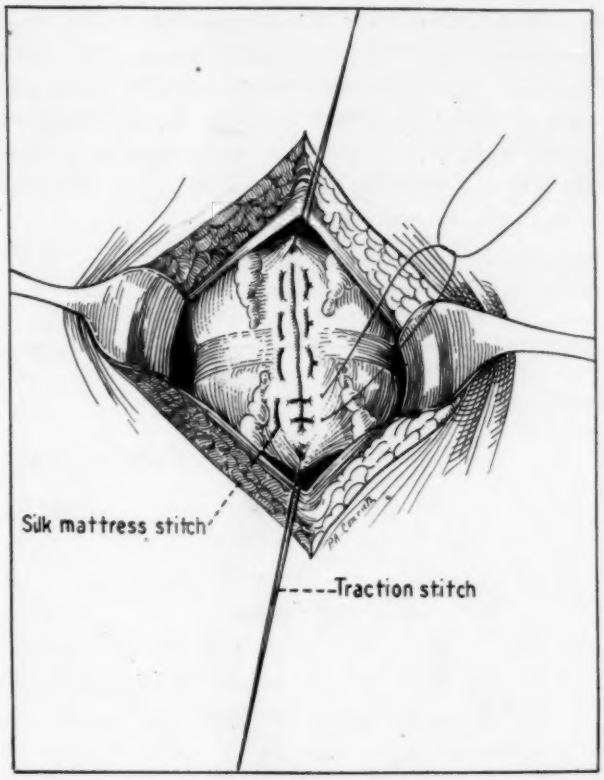

Fig. 5.—The second row is done with interrupted fine silk mattress sutures.

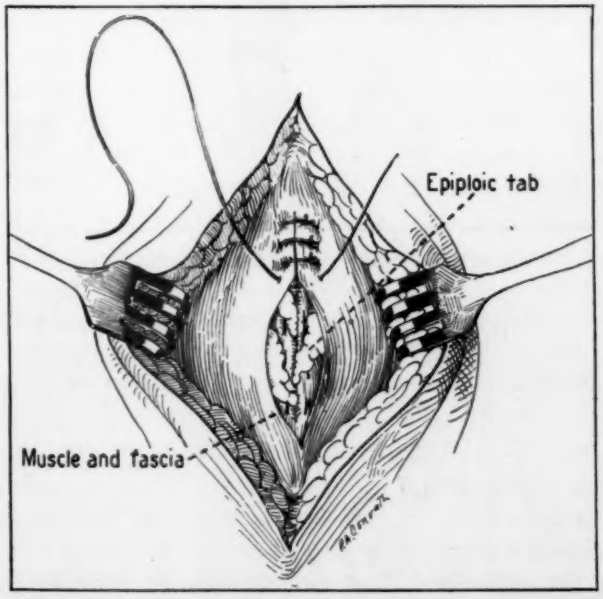

Fig. 6.—The epiploic fat tabs are tacked over the suture line. Closure of the fascia and muscle is done with chromic surgical gut.

present, were then tacked over the suture line. The fascia of the abdominal wall was closed with 00 chromic surgical gut; then a through and through fine Penrose drain was placed beneath the fat and brought out either angle of skin, after which silk was placed loosely in the skin.

For the cases in which there had been decided loss of bowel wall without creation of a double-barreled colostomy, intraperitoneal end to end anastomosis had to be performed.

Postoperatively we gave nothing by mouth for the first twenty-four hours, adequate intravenous alimentation being maintained meanwhile.

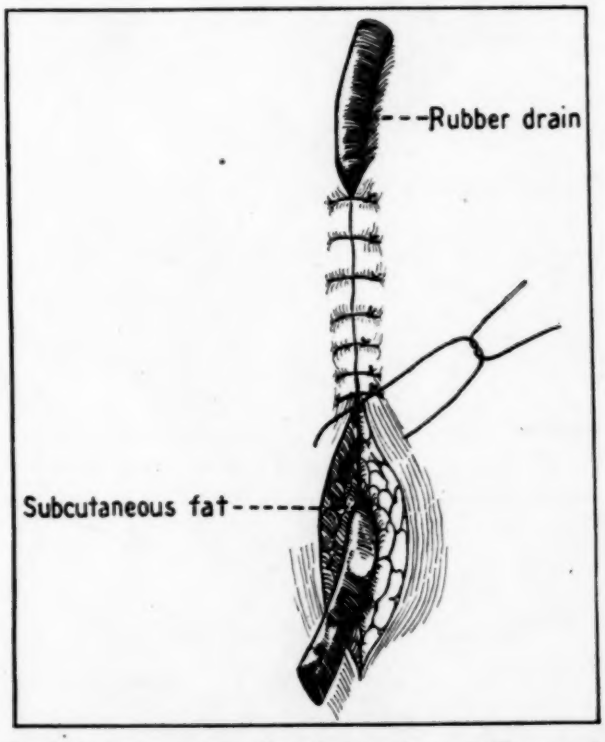

Fig. 7.—Subcutaneous through and through small Penrose drain.

Following this nonresidue liquids were permitted for the first week and then a low residue soft diet the second week. The tube, which is sufficiently small and flexible to cause little irritation of the anus, was removed about the fifth day, administration of liquid petrolatum, ½ ounce (16 Gm.) three times a day, having been started the previous day.

Failures to obtain closure of the colostomy should be and have been few in our series. One surgeon on our staff had two or three leaks before it was noted that he was dissecting the wall of the bowel from surrounding tissues without first circumcising the skin at the stoma.

It is thought that, following suture, leakage occurred through the traumatized and devitalized margins of bowel, for no further trouble was encountered after this practice was corrected.

Colostomy Closures in Fifteenth Hospital Center from June 1944 to March 1945

Hospital	Colostomies Closed	Simple Transverse Closure of Loop or Mikulicz After Spur Crushing	End to End Anastomosis	Postoperative Deaths
61st General Hospital	20	19	1	1
110th General Hospital	31	31	0	0
188th General Hospital	25	23	2	0
111th General Hospital	44	43	1	0
192nd General Hospital	60	40	20	0
186th General Hospital	28	18	10	0
97th General Hospital	12	12	0	0
104th Station Hospital	30	30	0	0
106th Station Hospital	30	27	3	0
91st General Hospital	23	0	23	0
Totals	298	238	60	1

SUMMARY

In summary it should be noted that in time of war injuries to the large bowel are complicated in a high percentage of cases by other major injuries, and it must be understood that the treatment must be fairly well standardized in order for the best over-all results to be obtained. Before closure is attempted care must be taken that colostomy spurs are adequately obliterated and that edema of the bowel and active infection of the wound are no longer present. Many closures can be kept extraperitoneal. In the case of closure of sigmoid colostomies we have employed a medium caliber latex rectal tube as a safety valve above the suture line and feel that this procedure has definite merit. Subcutaneous drains were placed in most closure wounds for forty-eight hours postoperatively, since these are contaminated wounds. Penicillin and sulfadiazine in standard doses were used in perhaps half of these cases. The value of succinylsulfathiazole as a bacteriostatic agent in the intestinal tract is well established, and its employment should be routine. Healing of the colostomies following closure was satisfactory in the large majority of instances, and there was only 1 postoperative death in 298 cases. This result is best explained by the fact that we were dealing with vigorous young men undergoing elective operation for whom were available unlimited supplies of such essentials as blood, plasma and chemotherapeutic agents for most thorough preoperative and postoperative treatment.

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ABSTRACT OF DISCUSSION

CHARLES W. MAYO, M.D., Rochester, Minn.: Dr. Bartlett's paper recalls the tribute due the physicians who were in the forward areas and whose primary management of traumatic injuries of the abdominal portion of the colon and of the rectum preserved so many lives and also the tribute due the Surgeon General, from whose office emanated the directives regarding the treatment of these injuries.

Surgeons, in general, are divided into two groups regarding closure of a colonic stoma, namely, those who prefer the intraperitoneal type of closure and those who prefer the extraperitoneal type of closure. As a rule, I believe that the mortality rate will be lower and the morbidity perhaps higher when the extraperitoneal method of reestablishing continuity of the colon is used than when the intraperitoneal method is used.

There are many details in the accomplishment of either method that must be observed for satisfactory results. Among them are the following steps: 1. The spur must be cut through adequately so that free passage of intestinal contents will result. 2. Sufficient time to allow subsidence of edema and inflammation must elapse, which varies in each case. 3. Fascia and muscle should be closed over the line of suture in the colon, and subcutaneous tissue and skin should be closed loosely or, perhaps preferably, by a secondary procedure about forty-eight hours later.

Not any one type of spur-crushing clamp will be satisfactory in all cases. One should have as many shapes and sizes of these clamps as one has scoops for exploration of the common duct. Several applications of clamps may be necessary, the main idea being not to attempt closure until the opening is adequate or a bit more than adequate.

The results of closure, as reported by Dr. Bartlett for the Fifteenth Hospital Center, are excellent. Extraperitoneal closure is safest; one can always repair a ventral hernia later on a live patient.

A MODIFIED TECHNIC FOR TOTAL GASTRECTOMY

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SURGICAL history records that Phineas Conner,[1] of Cincinnati, did the first complete gastrectomy on a human being in 1884. His patient died on the operating table before the operation could be completed. Thirteen years later, in 1897, Schlatter,[2] of Switzerland, successfully removed the stomach completely, and his patient survived one year and fifty-three days. In a discussion of Schlatter's case at a meeting of the *Deutsche Gesellschaft für Chirgurie* in 1898, Krönlein defined total gastrectomy as complete removal of the stomach with both the pylorus and the cardia and stated that, when examined, the specimen should show a portion of the duodenum at one end and a portion of the esophagus at the other. In a study of all total gastrectomies up to 1929, Finney and Rienhoff[3] emphasized the importance of Krönlein's definition, since they found that more than half of the operations recorded as total gastrectomies were really partial gastrectomies.

The technic used for complete removal of the stomach and restoration of the continuity of the alimentary tract has shown many variations since the successful gastrectomy of Schlatter (figs. 1 and 2). It is interesting to note that Schlatter's anastomosis between the esophagus and small intestine was an esophagojejunostomy. Since then many esophagoduodenostomies have been done, with and without the Murphy button. In recent years the operation of choice has been the esophagojejunostomy. A loop of jejunum has been placed either anterior or posterior to the colon.

Opinion has been divided concerning the value of a jejunojejunostomy between the ascending and descending portions of the jejunum below the jejunal anastomosis to the esophagus. There is some reason to doubt that an anastomosis between the two segments of the jejunal

From the Department of Surgery, University of Kansas Hospitals.

Presented at the meeting of the Western Surgical Association in Memphis, Tenn., Dec. 6, 1946.

1. Conner, P. S.: Report of a Case of Complete Resection of the Stomach, M. News, New York **45**:578, 1884.

2. Schlatter, C.: A Unique Case of Complete Removal of the Stomach: Successful Oesophagoenterostomy; Recovery, M. Rec. **52**:909, 1897.

3. Finney, J. M. T., and Rienhoff, W. F. J.: Gastrectomy, Arch. Surg. **18**: 140 (Jan.) 1929.

loop will drain much of the content of the portion of the jejunum proximal to the esophageal stoma.

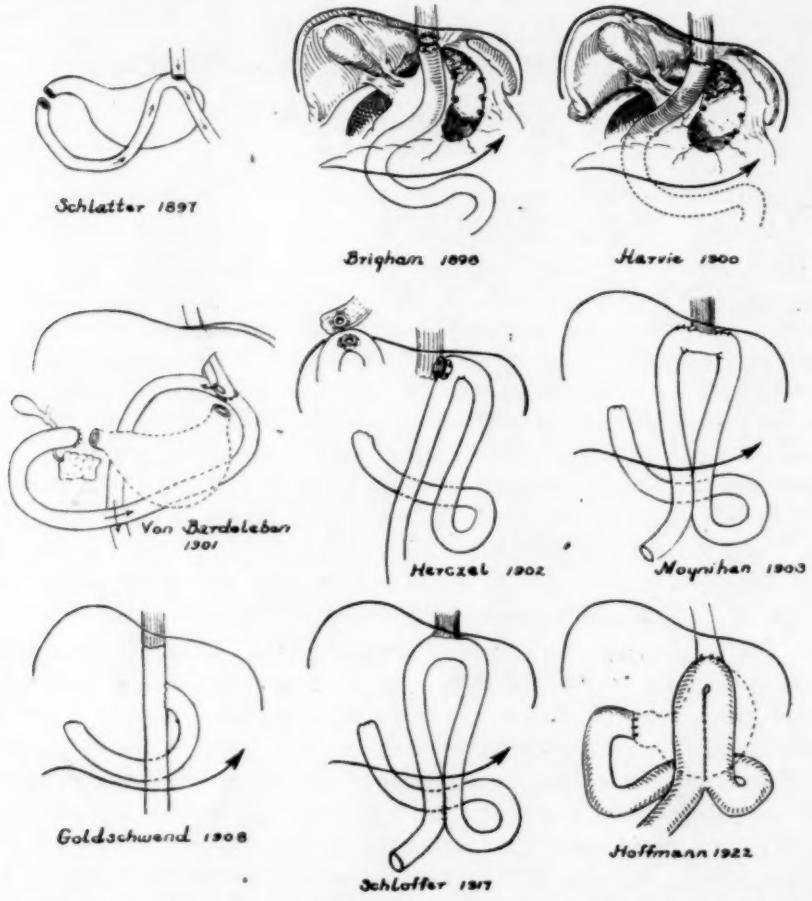

Fig. 1.—Sketches of the various methods used in the development of the technic of total gastrectomy.[4]

4. Brigham, C. B.: Case of Removal of the Entire Stomach for Carcinoma, Boston M. & S. J. **138**:415, 1898. Harvie, J. B.: Report of a Case Recovery After Gastrectomy for Carcinoma, Ann. Surg. **31**:344, 1900. Von Bardeleben, A.: Zur Kasuistik der totalen Magenextirpation, Deutsche med. Wchnschr. **27**:335, 1901. Herczel, E. V.: Beitrag zur totalen Extirpation des carcinomatösen Magens, Beitr. z. klin. Chir. **34**:336, 1902. Moynihan, B. G. A.: On Total Extirpation of the Stomach, with a Record of an Unsuccessful Case, Brit. M. J. **2**:1458, 1903. Goldschwend, F.: Operations- und Dauererfolge bei maligner Geschwulstbildung Magens, Arch. f. klin. Chir. **88**:218, 1908. Schloffer: Resektion des ganzen Magens, Deutsche med. Wchnschr. **43**:1216, 1917. Hoffman, V.: Eine Methode des "plastischen Magenersatzes," Zentralbl. f. Chir. **49**:1477, 1922. Schlatter [2]

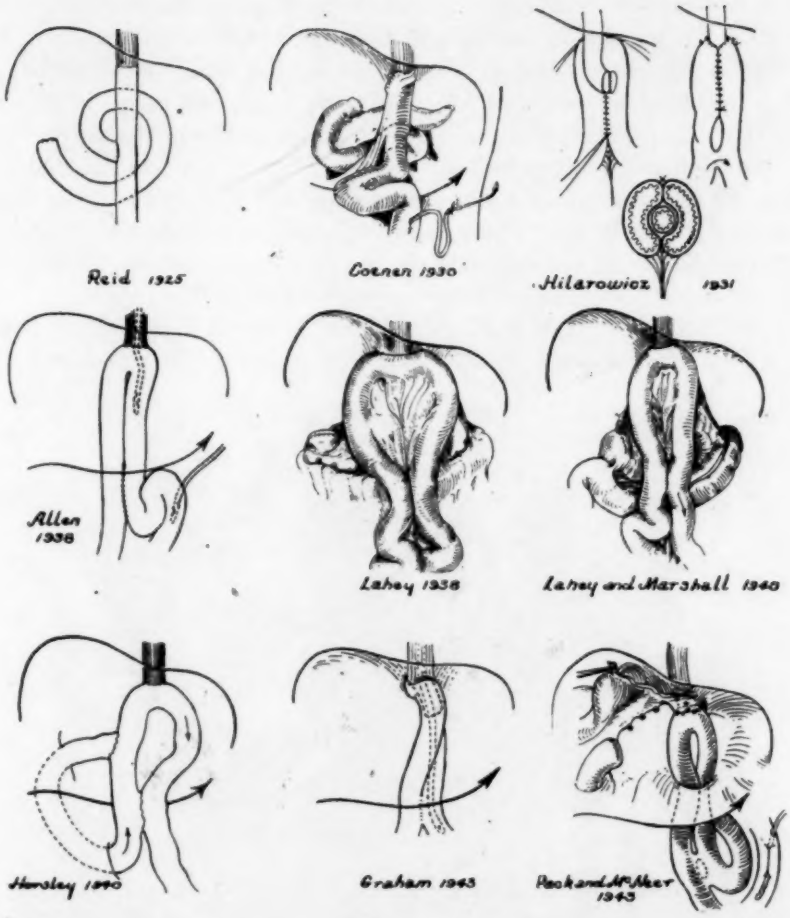

Fig. 2.—Sketches of various methods used in the development of the technic of total gastrectomy.[5]

5. (*a*) Reid, M. R.: Total Gastrectomy, Surg., Gynec. & Obst. **41**:667, 1925. (*b*) Coenen, H.: Zur Methodik der Totalextirpation des Magens, Deutsche Ztschr. f. Chir. **225**:391, 1930. (*c*) Hilarowicz, H.: Zur Technik der totalen Magenextirpation, Zentralbl. f. Chir. **58**:2613, 1931. (*d*) Allen, A. W.: Carcinoma of the Stomach with Special Reference to Total Gastrectomy, Ann. Surg. **107**:770, 1938. (*e*) Lahey, F. H.: Complete Removal of the Stomach for Malignancy: Report of Five Surgically Successful Cases, Surg., Gynec. & Obst. **67**:212, 1938. (*f*) Lahey, F. H., and Marshall, S. F.: Indications for, and Experience with, Total Gastrectomy, Ann. Surg. **119**:300, 1944. (*g*) Horsley, J. S.: Operative Surgery, St. Louis, C. V. Mosby Company, 1940, vol. 2, p. 1032. (*h*) Graham, R. R.: Total Gastrectomy for Carcinoma of the Stomach, Arch. Surg. **46**:907 (June) 1943. (*i*) Pack, G. T., and McNeer, G.: Total Gastrectomy for Cancer, Internat. Abstr. Surg. **77**:265, 1943.

DESCRIPTION OF MODIFIED TECHNIC

The stomach is emptied by an indwelling suction tube. A left paramedian incision is made from the angle betweeen the ensiform and costal margin to a point 4 to 6 cm. below the level of the umbilicus. This incision has furnished adequate exposure in all cases. After the decision has been made to remove the entire stomach, the cardiac end of the stomach is exposed and peritoneal flaps are constructed and reflected upward from the anterior and posterior surfaces of the lower end of the esophagus. These peritoneal flaps are made first to insure adequate length of esophagus below the diaphragm for anastomosis and to explore for extension of tumor or metastases in this region.

To increase exposure of the esophagus the left hepatic ligament is severed and sutured beneath the right side of the abdominal wall

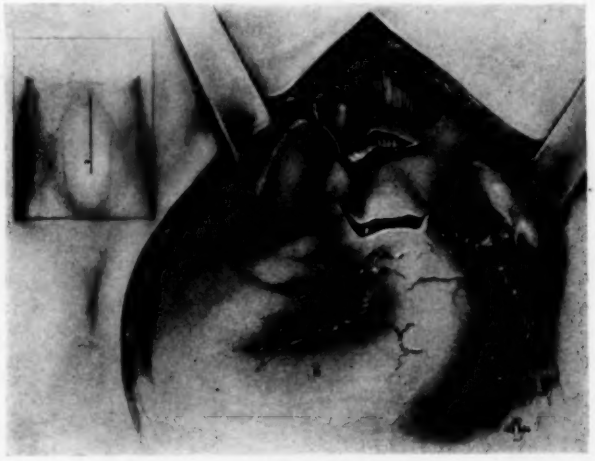

Fig. 3.—Technic of total gastrectomy. The insert shows the type of paramedian incision used. The ligament of the left lobe of the liver has been severed and sutured beneath the right side of the abdominal wall to retract the left lobe. An incision has been made for the formation of peritoneal flaps and exposure of the esophagus.

to displace the left lobe of the liver to the right (fig. 3). The duodenum is next freed and divided between clamps near the pylorus. The pyloric end of the duodenum is covered with gauze to prevent soiling. The distal end of the duodenum is closed with two rows of chromic surgical gut sutures reenforced with Lembert sutures of silk. The pyloric end of the stomach being used for traction, the gastrohepatic ligament is divided as far away from the stomach as possible, and vessels are ligated as the dissection proceeds. The omentum is completely removed with the gastrocolic ligament. When the spleen is approached the splenic vessels are ligated as near the spleen as possible. The spleen should be removed with the stomach if there is any infiltration of tumor tissue

along the vessels or if troublesome hemorrhage is encountered. (The spleen has not been removed in any of the 5 cases here recorded in the table.) By retraction of the stomach upward over the margin of the wound, the vessels near the cardia are easily exposed, severed and

Summary of Five Cases of Total Gastrectomy

Patient	Sex	Age, Yr.	Date of Operation	Type of Operation	Pathologic Change	Length of Life to Dec. 1, 1946
E. S.	Female	64	1/22/46	Postcolic	Reticulum cell sarcoma	Alive 10 mo.
A. G.	Male	60	7/11/46	Postcolic	Reticulum cell sarcoma	Alive 4½ mo.
E. G.	Male	69	7/16/46	Antecolic	Adenocarcinoma	Alive 4½ mo.
F. P.	Male	74	8/22/46	Antecolic	Adenocarcinoma	Alive 3½ mo.
J. B.	Male	76	10/ 2/46	Postcolic	Colloid carcinoma	Died on 40th postoperative day: hemiplegia and pneumonia

ligated. All areolar tissue is carefully dissected from the lower end of the esophagus, and the vagus nerves are severed to increase exposure. The esophagus is further freed and retracted downward by gentle, blunt

Fig. 4.—Technic of total gastrectomy (continued). The stomach and omentum have been freed and retracted. The insert shows the method of closing the duodenum with three rows of sutures.

finger dissection upward through the esophageal hiatus. From 5 to 8 cm. of the esophagus can usually be easily exposed below the diaphragm (fig. 4).

The gastric suction tube is withdrawn into the esophagus, and a right-angled clamp is placed across the esophagus about 1.5 cm. distal to the site chosen for the anastomosis. By placing the clamp transversely, the esophagus is flattened and widened near the suture line. This aids in the construction of as large a stoma as possible.

The jejunum is next divided between clamps about 15 cm. below the ligament of Treitz. The proximal end is covered with gauze and held aside for later anastomosis. The distal end of the jejunum is closed with three rows of sutures. The distal segment is then drawn

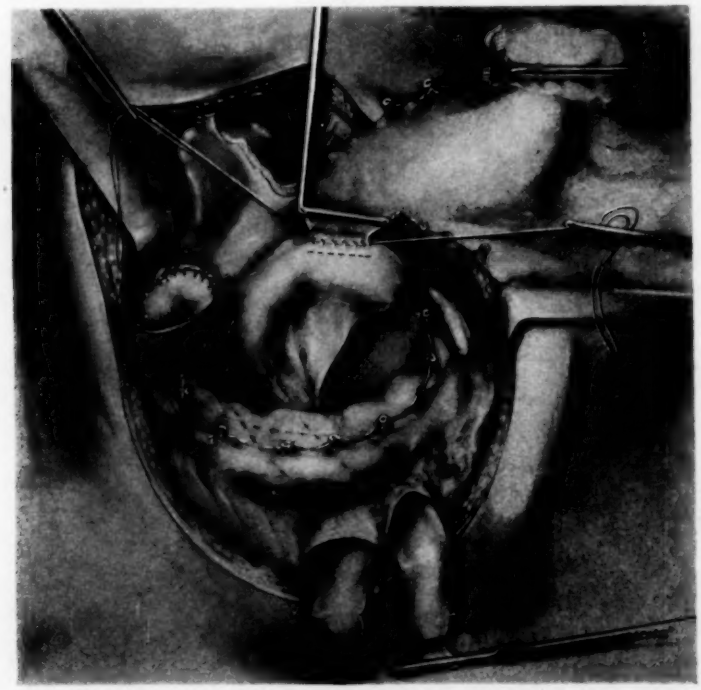

Fig. 5.—Technic of total gastrectomy (continued). The jejunum is divided 15 cm. below the ligament of Treitz. The end of the distal portion of the jejunum is closed, and the first row of sutures and lines of incision are shown in the esophagus and jejunum as the first step in end to side esophagojejunostomy.

through an opening in the mesocolon or anterior to the colon and anastomosed to the esophagus 5 to 6 cm. distal to its closed end. Interrupted silk stitches are used for the first row of sutures. A long suture is left at each end for traction. The esophagus and jejunum are then incised about 4 mm. from the suture line, and a row of no. 00 chromic surgical gut lockstitch sutures is used to unite the full thickness of both esophageal and jejunal walls. As this suture is placed, traction is maintained on the tension sutures to enlarge the esophageal opening

as much as possible. The anterior wall of the esophagus is next divided, and the stomach is removed. A surgical gut suture is used to unite the anterior margins of the esophagus and jejunum. An anterior row of silk Lembert sutures completes the anastomosis. The field is kept free from soiling by the right-angled clamp on the distal part of the esophagus, by constant suction through the tube in the esophagus and by suction in the wound (fig. 5).

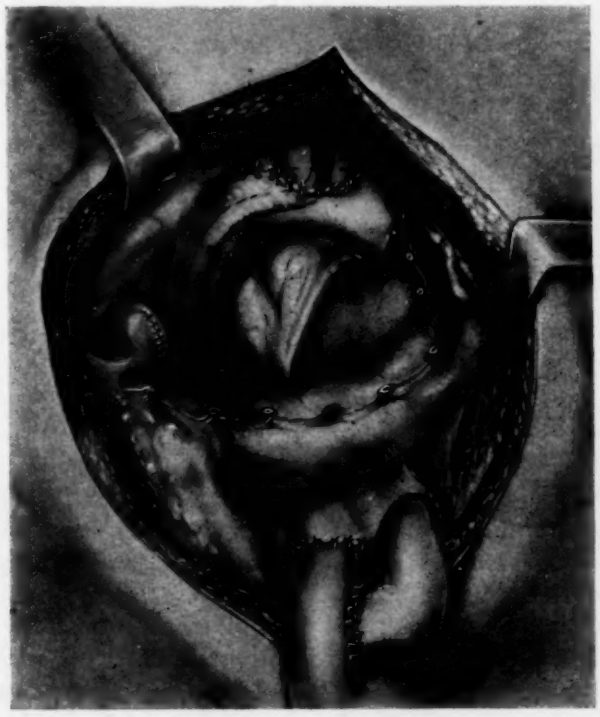

Fig. 6.—Technic of total gastrectomy (concluded). The end to side esophagojejunostomy is completed, showing peritoneal flaps sutured to the jejunum over the anastomotic line of suture. Lateral sutures have been placed to fix and suspend the jejunum. Postcolic end to side jejunojejunostomy is completed. The mesentery of the colon is sutured to the jejunum and the mesentery of the jejunum to close the defect in the mesocolon.

The line of anastomosis is covered, both anteriorly and posteriorly, with the previously constructed flaps of peritoneum. Finally, the jejunum is sutured to the diaphragm on each side of the anastomosis with two or three interrupted silk sutures to suspend the jejunum and decrease the tension on the anastomosis. When the anastomosis is completed the tube in the esophagus is passed into the jejunum. The suture in the left hepatic ligament is removed to release the left lobe of the liver.

An end to side anastomosis is made between the proximal end of the jejunum and the distal jejunum below the mesocolon. The margins of the incised mesocolon are sutured to the jejunum and its mesentery (fig. 6).

The abdominal wound in all cases has been closed with stainless steel wire and silk. The abdomen is drained through the upper end of the incision. The tube is left in the jejunum for four or five days. Small quantities of water are injected through the tube after the first day. Suction is continued as long as the tube is in the jejunum. When the tube is removed liquid feedings are begun, and they are given several times daily. After ten days semisolid food is given in five or six feedings each day.

The postoperative progress in 4 of the cases here recorded was uneventful (table). In the fifth, and last, patient hemiplegia developed four days following operation, which probably was responsible for his death, on the fortieth postoperative day.

COMMENT

The advantages of the technic described are: (1) direct entrance of food into the jejunum distal to the anastomosis without filling of the proximal part of the jejunum, as in the loop operation, (2) elimination of distention or delay in emptying of the proximal portion of a loop and (3) elimination of any regurgitation of the duodenal contents into the esophagus.

The mortality rate of total gastrectomy has been steadily decreasing since the first operation by Conner sixty-two years ago. The operative death rate recorded in 1929 by Finney and Rienhoff [5] in a collected series of sixty-two undoubted total gastrectomies was 53.8 per cent. In 1943 Pack and McNeer [51] collected 303 cases of total gastrectomy, with an operative mortality of 36.9 per cent. Eight consecutive cases of total gastrectomy were reported by Jones and Kehm [6] in 1945 without a death, and in 1946 Moreland [7] added 6 consecutive cases without a death.

With constantly improving methods of supportive treatment for patients submitted to surgical procedures and improvement and standardization of technic, it seems reasonable to predict that the mortality rate for total gastrectomy in the future will not exceed 10 to 15 per cent.

6. Jones, T. E., and Kehm, R. W.: Total Gastrectomy, Surg., Gynec. & Obst. **80**:534. 1945.

7. Moreland, R. B.: Total Gastrectomy, Arch. Surg. **52**:603 (May) 1946.

RUPTURED INTERVERTEBRAL DISK IN THE CERVICAL REGION

A Report of Twenty Cases

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AND
GUY L. ODOM, M.D.
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IT IS THE purpose of this paper to discuss briefly the diagnosis of the ruptured intervertebral disk in the cervical region and to correlate the clinical aspects of the syndrome with the pathologic-anatomic changes responsible. It is hoped that the report of this series of cases may contribute in some measure to the excellent reports that have been published about this clinical entity.

The ruptured cervical disk as a neurosurgical problem is nothing new, and there are numerous articles dating as far back as 1928 that deal with the ailment. In Stookey's work [1] the gross anatomic foundation of the clinical syndrome is clearly explained. His division into three clinical varieties based on the location of the intraspinal mass not only simplifies the conception of the condition but seems the only rational way of classification.

Stookey's group of 7 cases includes 6 cases of cord compression of one or both hemicolumns of the spinal cord or cord compression and what was interpreted as a lesion of the anterior horn accompanied with pressure on the long spinal tracts. Only 1 case was purely that of root compression and presented as such. Michelsen and Mixter [2] reported 8 cases, of which 1 was a case of cord compression and 7 were instances of root compression. Semmes and Murphey,[3] Spurling and Scoville [4]

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1. Stookey, B.: Compression of the Spinal Cord Due to Extradural Cervical Chordomas, Arch. Neurol. & Psychiat. **20**:275 (Aug.) 1928.

2. Michelsen, J. J., and Mixter, W. J.: Pain and Disability of Shoulder and Arm Due to Herniation of the Nucleus Pulposus of Cervical Intervertebral Disks, New England J. Med. **231**:279 (Aug. 24) 1944.

3. Semmes, R. E., and Murphey, F.: The Syndrome of Unilateral Rupture of the Sixth Cervical Disk, J. A. M. A. **121**:1209 (April 10) 1943.

4. Spurling, R. G., and Scoville, W. B.: Lateral Rupture of the Cervical Intervertebral Disks: Common Cause of Shoulder and Arm Pain, Surg., Gynec. & Obst. **78**:350 (April) 1944.

TABLE 1.—*Cases of Uncomplicated Root Compression*

Case	Disk Ruptured at	Sex, Age, Occupation	Duration of Symptoms	Character of Pain	Distribution of Pain	Distribution of Paresthesias	Reproduction of Pain or Paresthesias	Sensory Impairment
1 I. K. S.	5th cervical interspace	Woman 35 yr. housewife	3 yr.	Intermittent and stabbing; aggravated by movement of head and neck	Lower part of neck, left shoulder, entire left arm down to wrist	Distal forearm, hand, mostly thumb and index finger	Any movement of head and neck	Radial side of forearm, including thumb and 1st intermetacarpal space
2 C. L. M.	5th cervical interspace	Man 39 yr. lawyer	9 wk.	Intermittent, lancinating; aggravated by extension and rotation of head	Lower part of neck, left shoulder and radial aspect of entire arm, including thumb and index finger	Radial side of left hand, thumb and index finger	Extension and left lateral flexion of head	Radial side of forearm and hand
3 W. H. W.	5th cervical interspace	Man 52 yr. laborer	2 mo.	Intermittent, shooting; slightly affected by movement of head and neck	Left shoulder and radial side of arm to wrist	Thumb and index finger	Extreme movements of head and neck	Radial side of hand, including thumb and index finger
4 E. P. P.	5th cervical interspace	Woman 32 yr. housewife	3 yr.	Intermittent, lancinating; aggravated by movements of head and neck	Lower part of neck, left shoulder blade to posterior aspect of upper arm	Radial side of entire arm, including radial side of left hand, thumb, index and long fingers	Extension, flexion and left lateral flexion of head	Radial side of forearm and hand, including thumb
5 L. R. G.	5th cervical interspace	Man 32 yr. electrician	3 mo.	Intermittent; aggravated by movements of head and neck	Lower part of neck, left shoulder and entire arm	Right arm and hand	Extension, flexion and right lateral flexion of head	Extensor side of arm and hand
6 G. L. C.	6th cervical interspace	Man 39 yr. mechanic	3 mo.	Intermittent, lancinating; aggravated by movements of head and neck	Lower part of neck, left shoulder, entire left arm, 2d metacarpal bone	Same distribution as pain, including all fingers but centered on index finger	Flexion and extension of head	Extensor side of forearm, including 2d intermetacarpal space
7 V. D. C.	6th cervical interspace	Woman 59 yr. housewife	1 yr.	Intermittent, lancinating; aggravated by movements of head and neck	Lower part of neck, right shoulder, extensor side of entire arm, dorsum of hand, index, middle and ring fingers	Extensor side of arm, including index and long finger	Extension of head	Extensor side of entire arm, dorsum of hand, 1st to 4th intermetacarpal spaces, 1st to 4th fingers
8 V. L. T.	6th cervical interspace	Man 39 yr. salesman	1 yr.	Intermittent, lancinating; aggravated by movements of head and neck	Lower part of neck and entire left arm	Left hand	Extension and flexion of head	None
9 H. F. S.	6th cervical interspace	Man 51 yr. physician	6 yr.	Intermittent, shooting; aggravated by movements of head and neck	Lower part of neck, right shoulder, extensor side of upper arm to elbow	Extensor side of forearm, thumb and index finger	Extension of head	None
10 T. G. H.	6th cervical interspace	Woman 29 yr.	5 wk.	Intermittent, shooting; aggravated by movements of head and neck	Lower part of neck, right shoulder, extensor side of entire arm	Extensor side of arm and hand, centered in index and middle fingers	Extension and right lateral flexion of head	Narrow band over entire extensor side of arm and hand, including index and middle fingers
11 M. R. L.	6th cervical interspace	Man 56 yr. business man	9 wk.	Intermittent, lancinating; aggravated by movements of head and neck	Right shoulder extensor side of entire arm to wrist	Thumb and index finger	Rotation of face to right	None
12 M. E. Y.	6th cervical interspace	Woman 44 yr. housewife	3 mo.	Intermittent, shooting; aggravated by movements of head and neck	Lower part of neck, left shoulder, extensor side of entire arm to index, middle and ring fingers	Same distribution as pain	Flexion, extension and left lateral flexion of head	Extensor side of entire arm, dorsum of hand and fingers
13 E. F. E.	6th cervical interspace	Man 36 yr. painter	11 wk.	Constant but aggravated by movements of head and neck	Lower part of neck, left shoulder, extensor side of arm to midforearm	None	Flexion, extension and left lateral flexion of head	Three middle fingers
14 L. S. S.	6th cervical interspace	Man 47 yr. druggist	3 mo.	Intermittent, lancinating; aggravated by movements of head and neck	Right shoulder, extensor side of arm to midforearm	Dorsum of hand, centered on 2d metacarpal bone	Extension, right lateral flexion of head	Radial aspect of dorsum of hand, not including fingers
15 S. H.	6th cervical interspace	Woman	6 wk.	Constant, boring; aggravated by movements of head and neck	Left shoulder, extensor side of entire arm down to wrist	None	Flexion, extension and left lateral flexion of head	Extensor side of forearm, radial side of hand
16 G. M.	6th cervical interspace	Man 52 yr. laborer	6 wk.	Severe, shooting; not aggravated by movements of head and neck	Left shoulder blade, extensor side of upper arm toward wrist	Left index finger	Rotation of head or face to right	Left index finger

Sensory Impairment	Muscles Involved	Tendon Reflexes	Right	Left	Other Findings	Referring Physician
Radial side of forearm, including thumb and 1st intermetacarpal space	Biceps and deltoid; disuse atrophy of left shoulder girdle and left arm	Biceps..... Triceps..... Radial.....	+++ ++ ++	++ +++ ++	Remaining neurologic examination normal	Dr. L. Provinski, Jacksonville, Fla.
Radial side of forearm and hand	Deltoid, triceps, brachioradialis and extensors of wrist	Biceps..... Triceps..... Radial.....	+++ +++ +++	+++ ++ +++	Remaining neurologic examination normal	Dr. N. C. Wolfe, Burgaw, N. C.
Radial side of hand, including thumb and index finger	Deltoid	Biceps..... Triceps..... Radial.....	.. .. ..	.. .. ..	Neurologic examination not satisfactory	Dr. Fl. Jordan, Greenville, S. C.
Radial side of forearm and hand, including thumb	Deltoid, biceps, triceps and extensors of hand and fingers	Biceps..... Triceps..... Radial.....	++ ++ +	± + ±	The ruptured disk exerted pressure on the sixth cervical root and to a much less degree on the seventh cervical root because of Arnold-Chiari malformation in this patient	Dr. E. M. Hedgepeth, Chapel Hill, N. C.
Extensor side of arm and hand	Generalized weakness of right arm	Biceps..... Triceps..... Radial.....	± ++ +	++ + +	Remaining neurologic examination normal	Dr. G. C. Axelson, Martinsville, Va.
Extensor side of forearm, including 2d intermetacarpal space	Triceps, biceps, deltoid and pronators of hand	Biceps..... Triceps..... Radial.....	++ ++ +	+ + +	Remaining neurologic examination normal	Dr. J. T. Saunders, Asheville, N. C.
Extensor side of entire arm, dorsum of hand 1st to 4th intermetacarpal spaces, 1st to 4th fingers	Rhomboids, serratus anterior, triceps, extensors of wrist and deltoid	Biceps..... Triceps..... Radial.....	++ ++ ++	++ ++ ++	Remaining neurologic examination normal	Dr. S. R. Johnson, Dunn, N. C.
None	Triceps and deltoid	Biceps..... Triceps..... Radial.....	++ ± +	+++ + +	Remaining neurologic examination normal	Dr. E. T. West, Johnson City, Tenn.
None	None	Biceps..... Triceps..... Radial.....	++ + +	++ + +	Remaining neurologic examination normal	Dr. H. F. Starr, Greensboro, N. C.
Narrow band over entire extensor side of arm and hand, including index and middle fingers	Rhomboids, triceps, latissimus dorsi and biceps	Biceps..... Triceps..... Radial.....	++ ++ ..	+++ +++ ..	Remaining neurologic examination normal	None
None	Triceps, latissimus dorsi, serratus anterior, deltoid and biceps	Biceps..... Triceps..... Radial.....	++ + +	++ +++ +	Remaining neurologic examination normal	Dr. E. M. Hedgepeth, Chapel Hill, N. C.
Extensor side of entire arm, dorsum of hand and fingers	Triceps, serratus anterior and extensors of hand	Biceps..... Triceps..... Radial.....	++ ++ +	++ ± +	Remaining neurologic examination normal	Dr. R. M. Whitley, Rocky Mount, N. C.
Three middle fingers	Triceps, serratus anterior and deltoid, biceps	Biceps..... Triceps..... Radial.....	++ ++ ++	++ + ++	Remaining neurologic examination normal	Dr. J. R. Latham, New Bern, N. C.
Radial aspect of dorsum of hand, not including fingers	Triceps	Biceps..... Triceps..... Radial.....	++ + ++	++ ++ ++	Remaining neurologic examination normal	None
Extensor side of forearm, radial side of hand	.....	Biceps..... Triceps..... Radial.....	++ ++ ++	++ + ++	Remaining neurologic examination normal	Dr. F. M. Hesser, Durham, N. C.
Left index finger	Triceps, selective; disuse atrophy of left arm	Biceps..... Triceps..... Radial.....	++ ++ ++	++ ± ++	Remaining neurologic examination normal	Dr. V. J. Cox, Galax, Va.

and Bucy [5] all reported cases of pure root compression by a ruptured cervical disk. In the present series of 20 cases there are 16 of root compression (table 1) and 4 of cord compression (table 2).

In a review of the histories of the cases of Stookey's patients, it was observed that in 5 of the 6 cases of cord compression the condition began

TABLE 2.—*Cases of Combined Cord and Root Com*

Case	Disk Ruptured at	Sex, Age and Profession	Duration of Symptoms	Distribution of Pain	Distribution of Paresthesias	Sensory Impairment	Muscle Weak
17 Y. E.	5th cervical interspace, left side	Man 40 yr. school principal	5 mo.	Ulnar side of forearm, 3d, 4th and 5th fingers, left	Ulnar side of forearm; 3d, 4th and 5th fingers, left	Analgesia below third thoracic dermatome on right; hypalgesia below third thoracic dermatome on left; position sense normal in toes	Small muscles of le spastic weakness, of lower limb
18 M. G. H.	7th cervical interspace, transverse	Woman 35 yr. housewife	5 mo.	No pain recorded	Posterior surface of legs; soles	Dissociated sensory impairment below sixth thoracic dermatome bilaterally; position sense impaired in toes	Spastic weakness of limbs
19 L. M. G. B.	5th cervical interspace, transverse	Woman 51 yr. housewife	2 yr.	No pain recorded	Right hand and foot; left hand and foot	Slight impairment to fork (256 decibels) below elbow and knee bilaterally; position sense lost in toes on right	Decided general weak right arm and hand; general weakness of and arm; definite gen ness of both lower li
20 H. T.	3d cervical interspace, transverse	Man 43 yr. farmer	6 mo.	Left shoulder and arm	Left hand and left lower limb	Vibration sense to fork (128 decibels) lost in hands bilaterally, to fork (256 decibels) lost in feet bilaterally; position sense lost in fingers and toes; pain and temperature intact	Decided atrophy and of both shoulder gird arms, more so on left general weakness of limbs, more so on lef

with subjective complaints of pain in the arm and shoulder preceding paraparesis for a variable length of time. In Michelsen's and Mixter's case cord compression began with pain in the shoulder and arm twenty-three years before the onset of paraparesis. In 2 of our 4 cases of cord compression the syndrome began with pain in the neck and shoulder

5. Bucy, P. C., and Chenault, H.: Compression of Seventh Cervical Nerve Root by Herniation of Intervertebral Disk, J. A. M. A. **126**:26 (Sept. 2) 1944.

before the onset of paraparesis. These facts show a discrepancy of 7:1 in the proportion of root and cord compression in Michelsen and Mixter's series [2] as compared with 16:4 in the present group and 1:6 in that of Stookey,[1] the earliest reported series. This discrepancy is strongly suggestive of an earlier recognition in the more recent reports.

Combined Cord and Root Compression

Muscle Weakness	Genito-urinary Function	Reflexes	Right	Left	Other Findings	Referring Physician
Small muscles of left hand; spastic weakness of left lower limb	Impaired	Biceps	++	++	.....	Dr. W. E. Cook, Mebane, N. C.
		Triceps	++	++		
		Radial	++	++		
		Abdominal	0	0		
			0	0		
		Knee jerk	++	++++		
		Ankle jerk	++	+++		
		Plantar	↓	↑		
Spastic weakness of both lower limbs	Unimpaired	Biceps	++	++	.....	Dr. J. C. Shuler, Durham, N. C.
		Triceps	++	++		
		Radial	++	++		
		Abdominal	0	0		
			0	0		
		Knee jerk	++++	++++		
		Ankle jerk	+++	+++		
		Plantar	↑	↑		
Decided general weakness of right arm and hand; moderate general weakness of left hand and arm; definite general weakness of both lower limbs	Unimpaired	Biceps	+++	+++	.....	Dr. C. Ewell, Rocky Mount, N. C.
		Triceps	++	++		
		Radial	++	++		
		Abdominal	+	+		
			0	0		
		Knee jerk	++++	++++		
		Ankle jerk	+++	+++		
		Plantar	↑	↑		
Decided atrophy and weakness of both shoulder girdles and arms, more so on left; moderate general weakness of both lower limbs, more so on left	Unimpaired	Biceps	+	++	Horner's syndrome on left side	Dr. R. G. Tyndall, Kinston, N. C.
		Triceps	+	+++		
		Radial	+	+++		
		Abdominal	0	0		
			0	0		
		Knee jerk	+++	+++		
		Ankle jerk	++	++		
		Plantar	↑	↑		
		Hoffmann	0	+		

The differences between the cervical and the lumbar portion of the spinal canal—and particularly the difference between the contents of these two most mobile sections of the canal—are those of dimensions and anatomic function. The cervical canal contains the cervical nerve roots and the cervical cord, whereas the lumbar canal contains the cauda equina and no spinal cord below the first lumbar vertebra. In the cervical canal, within the dural sheath, the cord is anchored by the

dentate ligament on both sides and the nerve roots pass through their intervertebral foramens almost instantly after exit from the cord. Because of these characters the neural structures are relatively immobile. When one considers that the relation between the cervical interspaces and their corresponding nerve roots is a much closer one than is the case in the lumbar portion, it becomes evident that root compression in the cervical canal will occur with much greater localization than that in the lumbar portion. Though the cervical intervertebral disks and, therefore, the disk protrusions also are much smaller than those in the lumbar region, it is nevertheless justifiable to say that the potentiality for compression of a nerve root is much greater in the cervical region.

The relative immobility of the cervical neural structures explains the rapidity of onset of symptoms and signs and why the actually small but relatively large protrusions of the ruptured disk may result in selective pressure on one hemilateral or even hemianterolateral column only. The localization of unilateral compression of a single root in the cervical part of the spine due to the close relation of interspace and corresponding nerve root is, however, slightly altered in a few instances when a single protrusion exerts pressure on two adjacent nerve roots. This will be encountered in patients with Arnold-Chiari malformation, in which the disproportion of growth of spinal cord and spinal column will result in a parallel, longitudinal passage of the cervical roots for a short distance (case 4). Arnold-Chiari ailment is not common, however, and such a coincidence will be a rarity.

In the lumbar canal the two main reasons for compression of multiple roots are (1) multiple ruptured disks and (2) large protrusions that extend medially. In the cervical portion of the spine multiple ruptures are possible for the same reasons as in the lumbar part of the spine, namely, because of the extensive movements and relatively poor support of this part of the spine. The small series of cases reported here, however, does not include such an instance.

Large protrusions in the cervical region will cause compression of the spinal cord. The resulting syndrome, dominated by signs related to the cord, will lead to a diagnosis of a lesion in the cord that may be misleading as to the causation. At the time of rupture a large protrusion may occur suddenly and compress the cord instantly. The syndrome will then begin and remain as that of a lesion of the cord, and thus it is logical to distinguish between cord compression and root compression resulting from a ruptured cervical disk. There are, however, reasons to assume that in several instances these two varieties mark successive stages in the pathogenesis of a ruptured cervical disk and that the pathogenesis at times should be divided into three periods: (1) period of root compression; (2) period of unilateral cord compression with or without masked root compression, and (3) period of bilateral cord compression with masked unilateral or bilateral root compression.

The most vulnerable point in the annulus fibrosus and posterior longitudinal ligament is, as in the lumbar portion of the spine, situated laterally in relation to the spinal canal or anterior to the corresponding nerve root and not the spinal cord itself. Therefore, in the majority of cases compression of the root will occur first and the outstanding com-

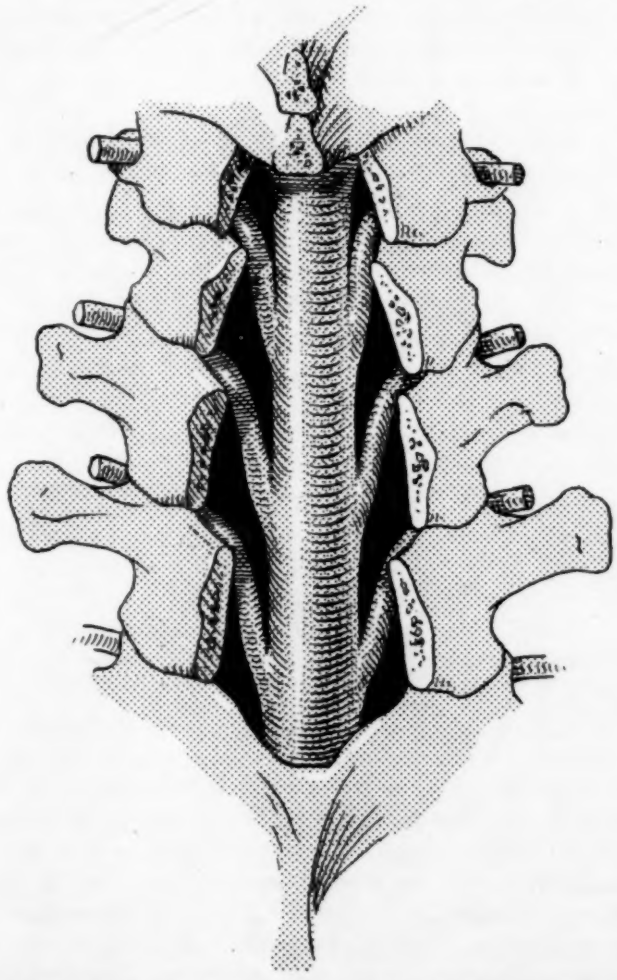

Fig. 1.—Drawing of the cervical canal, containing the cervical nerve roots and cervical cord, showing relations of roots and cord in a case of Arnold-Chiari malformation.

plaint will be radicular pain and paresthesias referable to the dermatome of that root.[6] The dominating neuropathologic signs, if present, will also be referable to the peripheral distribution of that same root. It will be

6. Foerster, O.: The Dermatomes in Man, Brain **56**:1 (March) 1933.

possible to exclude a lesion of the cord by the absence of ipsilateral signs in the pyramidal tract and contralateral spinothalamic signs. Certain movements of the head and neck will reproduce the radicular pain and paresthesias, and, consequently, this along with the absence of tenderness of the nerves and muscles will rule out the possibility of a lesion of the peripheral nerves.

This stage of root compression may not advance any further, and the syndrome may remain as such, with remissions and exacerbations for years.

LATERAL PROTRUSIONS WITH ROOT COMPRESSION UNCOMPLICATED BY CORD COMPRESSION

The cases of lateral protrusions with root compression are summarized in table 1. Experience reveals that rupture of an intervertebral cervical disk takes place at the fifth and sixth interspaces in most of the cases. This is probably due to the greater mobility of these joints and

Fig. 2.—Uncomplicated root compression as a result of a ruptured disk.

is comparable to the common lesion in the fourth and fifth interspaces in the lumbar portion of the spine. This does not mean, however, that ruptures are confined to these interspaces, as may be seen in the tables. Nevertheless, they are the commonest sites of rupture, and the syndromes arising are now so well known that the diagnosis of a ruptured disk at one of the two aforementioned interspaces can be made clinically with great certainty as long as the result of the rupture is an uncomplicated root compression (fig. 2).

In all probability all ruptures of intervertebral cervical disks are traumatic in origin, but it is not always possible to obtain a history of trauma. A long time may have elapsed since the initial injury, and the patients may have forgotten or, as frequently is the case, they simply have not been asked about such an initial injury. Further, the injury may have been so mild that the patient failed to connect it with the pain

in the shoulder and arm later developing. By careful questioning, a history of an initiating trauma will be obtainable in nearly all cases.

The subjective complaints are almost invariably those of pain in the lower part of the neck that soon afterward is overshadowed by complaints of pain radiating from the neck to the shoulder and arm, accompanied with paresthesias in a more distal area. The radicular pain will differ both in distribution and in extent; it will at times involve only the shoulder and upper arm, but it may extend to the fingers. The distribution will vary, and the pain may be referred to the supraclavicular fossa, pectoral region, back of the shoulder, shoulder blade, radial side of arm and fingers, extensor side of the upper arm and forearm and other regions.

The paresthesias will be felt in the same distribution as the pain but usually will extend more distally than does the pain. For example, when the sixth cervical root is compressed, the distribution of paresthesias will be the radial side of the forearm, thumb and index finger, whereas it will be the extensor side of forearm, dorsum of the hand and one or all of the three middle fingers when the seventh cervical root is compressed.

Both the pain and the paresthesias are nearly always aggravated by movements of the head and neck, which result in direct compression of the nerve root. In most cases pain and paresthesias are brought on also by increased intraspinal pressure resulting from distention of the cervical rachidian veins.

The objective signs may be divided into mechanical defensive signs and neuropathologic signs. The former, which act to protect against sudden compression of the nerve root, are the tilted head and wry neck; the tenderness to manipulation of the lower cervical spinous processes (a procedure that frequently will reproduce the radicular pain), and, last, the most reliable sign of a ruptured cervical disk at the fifth and sixth interspaces, tenderness to hyperextension, flexion and lateral flexion of the head toward the side of pain, manipulations which seldom fail to call forth the patients' pain and paresthesias in all their extent.

The neuropathologic signs that may be associated with the mechanical defensive ones are indicative not only of root compression but also of the root compressed and are, therefore, localizing in character. They may not be observed for some time after the onset of pain and paresthesias. They consist of selective hypotonia and weakness and, later, fibrillations and atrophy of certain of the arm muscles, undissociated sensory impairment in certain dermatomes and, last, diminution of certain of the tendon reflexes of the arm. These neuropathologic signs are indicative of degeneration of the nerves and are of much graver significance than the neuropathologic complaints, which only indicate irritation of the root. Both the subjective complaints and the defensive signs will disappear after removal of the ruptured disk; whether the neuropathologic signs do so or not will depend on the duration of root compression.

DIAGNOSIS

The diagnosis of the ruptured cervical disk is primarily clinical, and the history and subjective complaints are of the greatest aid in arriving at an early diagnosis. The ability to bring on the pain and paresthesias by manipulation of the lower cervical spinous processes and by hyperextending, flexing and laterally flexing the head toward the side of pain will confirm the presumptive diagnosis of a ruptured cervical disk. This will be possible with infrequent exceptions as long as the clinical syndrome is that of uncomplicated root compression. As will be seen in the tables, a ruptured disk at the fifth cervical interspace may be diagnosed when pain and paresthesias are referred to the radial side of the arm, thumb and index finger; the sensory impairment, if present, involves the same area or part of it; there is weakness, primarily of the deltoid and biceps muscles, and the biceps reflex is diminished.

In a like manner a rupture at the sixth cervical interspace may be diagnosed when the pain and paresthesias are referred to the extensor side of the arm, dorsum of the hand and one or all of the three middle fingers; the sensory impairment, if present, involves the same area or part of it, there is weakness primarily of the triceps muscle and the triceps reflex is diminished. This empiric division conforms fairly well with the segmental representation of current sensory and motor tables.

Apparently the sensory areas supplied by the sixth and seventh cervical roots overlap somewhat, both in the anatomic arrangement and in the patient's interpretation. Therefore, the examiner will have to approach the evaluation of the hypalgetic areas of the skin with a certain critical judgment. As to the involvement of muscles, the deltoid and biceps muscles seem to be earliest and most frequently affected when the sixth cervical root is compressed, and the triceps muscle is affected when the seventh is involved. Because of the complicated segmental representation of the muscles of the arm and shoulder, it is difficult to go any further in the evaluation of muscular weakness as a localizing sign. However, one will find the involvement of these three muscles reliable when weakness of the muscles is present.

ROENTGENOGRAMS OF THE BONY STRUCTURES

At times narrowing of the interspace in question may be seen in the roentgenogram in the lateral view. An unusually straight neck or absence of the physiologic cervical lordosis may be seen also in the same view. The oblique view may or may not show localized arthritic changes and narrowing of the intervertebral foramen in cases of lateral protrusion. In such instances these changes can be seen only on the one side, necessitating oblique views of both sides for comparison.

These roentgenologic findings are positive evidence of a ruptured disk, but their absence by no means rules out the possibility of rupture

of a disk. In cases of cord compression roentgenograms of the bony structures can furnish only negative evidence.

MYELOGRAPHY

Myelography is necessary in all cases of cord compression for diagnosis of the level involved. In instances of lateral protrusion and root compression it may be necessary to employ this valuable diagnostic method principally to prove the presence of a ruptured disk when other differential diagnostic ailments have been strongly suggested.

Myelography is an accurate method of diagnosis whether iodized poppyseed oil or Pantopaque (ethyliodophenylundecylate) is used as contrast medium. In cases of lateral protrusion the shadow of the contrast medium is often so characteristic that an etiologic diagnosis can be made from the roentgenograms alone. The defect in the shadow of the contrast medium is well rounded, occupies a lateral position over the interspace in question or, in cases of small protrusions, only hinders penetration of the contrast medium into the sleeve of the compressed root.

DIFFERENTIAL DIAGNOSIS

The pathologic conditions that usually cause difficulties in the recognition of a ruptured cervical disk with uncomplicated root compression will be discussed briefly.

1. *Cervical Arthritis.*—Cervical arthritis, which is primarily an ailment of old age, is associated with pain in the neck, aggravated by motion of the head and neck, and with diffuse tenderness to palpation of the cervical part of the spine. It may also result in radicular pain of distribution over the root. The local pain and tenderness are easily explained; the radicular pain is less so.

As in all conditions of diffuse arthritis of the spine, the intervertebral disk has, to a greater or less extent, lost its dynamic capacity. The interspaces are narrowed, and the usual irritative, hypertrophic spur formations occur at the edges of the bodies of the vertebrae. As a matter of fact, these spurs will occur at the posterior lateral border of the bodies as well as on the anterior border and can affect the roots as they pass through the narrowed intervertebral foramens.

It is feasible to assume that in such cases irritation of the root is due to destruction or damage to the intervertebral disk, even though the latter cannot be classified as a ruptured disk. The reports of calcified ruptured disks probably deal with cases of excessive hypertrophic arthritis of the cervical portion of the spine. The history, however, will be different, since there will have been a long, chronic course without initial trauma. The neurologic examination will as a rule fail to show the objective neuropathologic changes of root compression, although the complaints will be those resulting from genuine irritation of the root. The

roentgenograms usually will show diffuse arthritic changes of the cervical and lumbar portions of the spine, if not the entire spine, and, frequently, narrowing of one or two of the intervertebral foramens. These findings, however, allow only the diagnosis of arthritis unless the abnormality is confined to only one interspace. Lumbar puncture, manometric readings and estimation of total protein contents will yield no decisive results, and myelography will show only evidence of the prominent posterior borders of the interspaces. If the subjective pain and paresthesias are sufficiently severe, the description will be accurate enough to allow localization and decompression of the affected root or roots.

2. *Scalenus Anticus Syndrome.*—Scalenus anticus syndrome, which is divided into nervous and vascular varieties, will often be mentioned in differential diagnosis. The radiation of pain and paresthesias confined to the ulnar or ulnar-median distribution is customarily designated as the scalenus anticus syndrome. It has never been adequately explained why symptoms and signs from the first dorsal and eighth cervical nerve roots predominate over the signs from the seventh, sixth and fifth roots following compression of the brachial plexus where it passes between the scalenus medius and anticus muscles. It is possible, as suggested by Spurling,[4] that the scalenus anticus syndrome in its broadest sense is superimposed on a ruptured cervical disk and that it is based wholly on vascular changes due to compression of the subclavian artery. The radicular pain and the selective paresthesias, on the other hand, should be considered as the results of true root compression and not as due to compression of the plexus. In the present series the vascular signs and symptoms have not been listed in the tables, but that does not mean that they were not present. At any rate, it should be observed as a general rule that the scalenus anticus muscle should not be sectioned until myelography has been performed, the assumption being that the spasm of the muscles of the neck is a defensive sign and present only to prevent sudden pressure on a nerve root by a ruptured disk at the seventh cervical interspace.

3. *Laminar Fractures in Cervical Region.*—Laminar fractures in the cervical region have a similar history to that of ruptured disk insofar as initial trauma and persistent radicular pain are concerned. Roentgenograms of the cervical part of the spine, particularly the oblique views, are of the greatest importance in these cases, as the laminar fragment may be seen protruding into the intervertebral foramen. The clinical picture is similar to that of a ruptured cervical disk and at times is indistinguishable until the lesion is exposed at operation.

4. *Cervical Rib or Elongated Transverse Process of the Seventh Cervical Vertebra.*—Cervical rib or an elongated transverse process of the seventh cervical vertebra is often found accidentally on roentgenograms without any subjective or objective signs of involvement of the

nerves. It will at times cause pain and paresthesias of the shoulder and arm due to pressure on the plexus and artery, and accordingly that syndrome can be divided into a nervous and a vascular one. However, the course of such a disability will have been chronic and gradual and without remission and exacerbations. The pain will be aggravated by movements of or downward pull on the arm or other movements. The objective findings will be dominated by the vascular signs, that is, abolition of the radial pulse, difference in blood pressure in the two arms and difference in temperature of the arms, and certainly the rib, if not palpable, will be seen in the roentgenograms. If the pain does not subside after removal of the rib, myelography should be performed.

5. *Subdeltoid and Subacromial Bursitis.*—Subdeltoid and subacromial bursitis should cause only slight difficulties in differential diagnosis when the history is examined. There are local tenderness and limitation of movement in the shoulder joint, and roentgenograms of the shoulder may show the calcification.

6. *Brachial Neuritis.*—Brachial neuritis gives pain in the entire arm which is diffuse and constant in nature and not aggravated by motion of the head and neck. There is exquisite tenderness to palpation along the course of the affected nerves and pronounced tenderness of the muscles, neither of which is present in root compression due to ruptured cervical disk.

7. *Pancost's Tumor.*—Pancost's tumor may be mentioned as a rarity. It will give pain in the shoulder and axilla and eventually Horner's syndrome will develop. Roentgenograms of the chest will reveal a homogeneous shadow at the apex of the lung and thus disclose the true nature of this ailment.

8. *Cervical Radiculitis.*—Cervical radiculitis, which is said to involve most commonly the sixth and seventh nerve roots, may be mentioned here. Root compression cannot be distinguished by any other means than myelography or exploration.

LARGE PROTRUSIONS WITH ROOT COMPRESSION COMPLICATED BY CORD COMPRESSION

If the protrusion occurs medially (fig. 3 *A*) or if, as is clearly detectable in the histories in 9 of the 11 cases of cord compression reported,[7] the protruding ruptured disk proceeds farther and turns over in the medial direction across the interspace and produces pressure on the ipsilateral half of the cord (fig. 3 *B*), the stage of unilateral cord compression is established. This is possible without much displacement of the cord, so that transmitted pressure on the ipsilateral part of the

7. Stookey reported 6 cases of cord compressoin, Michelsen and Mixter 1 case of cord compression and the present series 4 cases of cord compression.

posterior section of the column may not be present due to the fixation of the cord. In all likelihood the root compression is present nonetheless, but it will already be masked by signs related to the cord, which are signs in the ipsilateral pyramidal tract and contralateral spinothalamic signs with indefinite sensory level, several segments below the true lesion. The signs related to the root, weakness of the muscles and fibrillations and diminution of the tendon reflexes in the arm will be ascribed to a lesion in the anterior horn. It will no longer be possible not to suspect a tumor of the cord and to subject such a patient to myelography. The cases of root compression complicated by cord compression are summarized in table 2.

If myelography is not done and the diagnosis not made, in such a case unilateral cord compression will likely pass into the stage of bilateral cord compression by further expulsion of the fragment of the disk

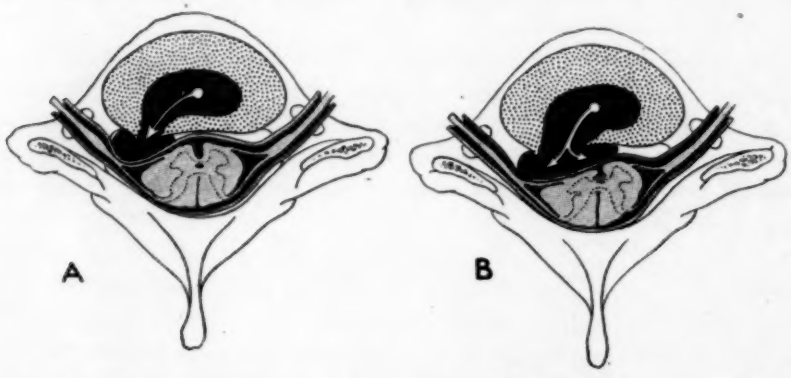

Fig. 3.—Root compression complicated by cord compression. *A*, medial protrusion with pressure of the disk on the ipsilateral half of the cord. *B*, large medial protrusion with pressure on both hemicolumns of the cord.

through the tear and further extension of it in medial direction. If so, the signs related to the root may no longer be recognizable as such. The sensory impairment in one or both upper extremities will be confined to the fingers and hand and easily interpreted as peripheral in nature. The unilateral or bilateral, disassociated or undisassociated sensory loss in the lower limbs may or may not extend up onto the trunk. The wasting and weakness in one or both upper extremities will be associated with spastic weakness of the lower limbs. Therefore, it is not surprising that such a syndrome is frequently diagnosed as due to syringomyelia or to an intramedullary tumor.

If there are signs from the posterior columns in addition to the others, a possible diagnosis of subacute combined degeneration will also be entertained in many of these cases. This is not at all unreasonable, since in the great majority of these cases a lumbar puncture will

reveal normal manometric readings on a Grant Cone test and the total protein content of the spinal fluid frequently within normal limits. Therefore, the true nature of the lesion probably will not be recognized until myelography has been performed.

The complaints during these two later stages are likely to be those of indefinite pain in the neck and one or both shoulders, but probably these often will be overshadowed by complaints of weakness in one or both lower limbs or even ataxia of the lower limbs.

DIAGNOSIS AND DIFFERENTIAL DIAGNOSIS

The problems of diagnosis after compression of the cord or when compression has been present from the beginning are twofold, namely, those of eitology and those of spinal level. If a history of trauma to the neck with transient radicular pain and paresthesias is obtained, even if it preceded the paraparesis by many years, it is highly probable that the cord compression is caused by a ruptured disk. Otherwise an etiologic diagnosis will not be made definitely until the lesion is exposed. The diagnostic procedures for the determination of the level of the lesion will be the same as those for a tumor of the spinal cord, and the condition to be considered in the differential diagnosis will be the same as those in the instance of tumors of the spinal cord.

LUMBAR PUNCTURES WITH MANOMETRIC READINGS AND ESTIMATION OF TOTAL PROTEIN CONTENT OF THE SPINAL FLUID

In cases of lateral protrusions, the manometric readings will be normal and the total protein levels of the spinal fluid within normal limits. In cases of large protrusions, the manometric readings often will be

TABLE 3.—*Results of Manometric Reading and Examination of Spinal Fluid for Total Protein Content*

Case	Manometric Reading	Spinal Fluid Total Protein, Mg./100 Cc.	Case	Manometric Reading	Spinal Fluid Total Protein, Mg./100 Cc.
1. L. K. S.	Not done	Not done	11. M. R. L.	Normal	24
2. C. L. M.	Normal	57	12. M. E. Y.	Normal	45
3. W. H. W.	No report	No report	13. E. F. E.	Normal	58
4. E. P. P.	Normal	32	14. L. S. S.	Normal	No report
5. L. R. G.	Not done	Not done	15. S. H.	Not done	Not done
6. G. L. C.	Normal	84	16. G. M.	Not done	Not done
7. V. D. C.	Normal	43	17. Y. E.	Partial block	Pandy 2+
8. V. L. T.	Normal	52	18. M. G. H.	Partial block	62
9. H. F. S.	Normal	No report	19. L. M. B.	Normal	29
10. T. G. H.	Normal	33	20. H. T.	Partial block	113

normal and the increase in the total protein levels of the spinal fluid will be so small that no conclusions can be drawn. In the few cases in which the subarachnoid block is complete, the manometric readings and greatly increased total protein levels in the spinal fluid still will not give more than a hint of the level of the lesion.

OPERATION

The operative procedure for cervical disks is somewhat similar to that for the lumbar region, but it is more of a risk. The patient is placed in a sitting position, in the Craig headrest, with the head flexed forward. This position not only decreases bleeding but aids greatly in the exposure of the lesion. Because of flexion of the neck, solution of tribromoethanol and ether administered intratracheally is preferred as the anesthetic in order to prevent obstruction of the airways. Local anesthesia may be

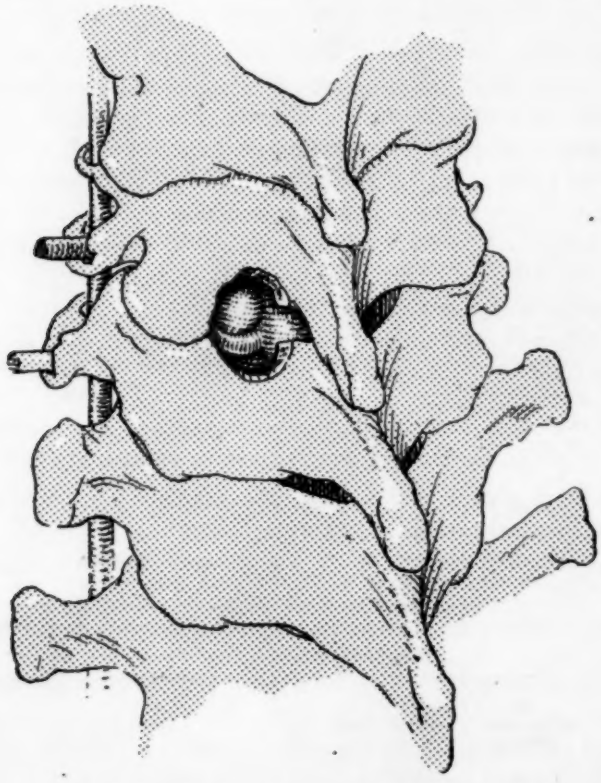

Fig. 4.—Exposure of ruptured cervical disk.

used and is helpful in locating the correct interspace by application of pressure over the ligamentum flavum, as suggested by Semmes; this, however, usually is an extremely uncomfortable procedure for the patient. A midline incision is made from the spinous process of the fourth cervical to the first dorsal spinous process, and the posterior muscles in the neck are separated in the midline by close to blunt dissection to decrease bleeding. The muscles are then stripped subperiosteally from the spinous processes and the laminas of the fifth, sixth and seventh cervical vertebrae on the side of the lesion. The roentgenograms should

be studied carefully in regard to the spinous processes, since in the cervical region there is not a definite landmark comparable to the sacrum, which is so extremely helpful in orientation in the lumbar region. Usually there is a pronounced bifurcation of the tip of the fifth cervical spine and sometimes also of the sixth, but that of the latter is always much shallower. The seventh cervical spine, the longest and most prominent, ends in a smooth rounded nodule.

After exposure of the laminas, the attachment of the ligamentum flavum is separated from the anterior surface of the lamina above. The caudal one third is then removed with rongeurs from this lamina and the removal carried well laterally (fig. 4). In order to accomplish the lateral removal, it may be necessary to use a small dental chisel. The ligamentum flavum, which is much thinner than that in the lumbar region, is removed by sharp dissection. In most cases this will give an adequate exposure for exploring the interspace, but frequently it is necessary to remove a small portion of the upper, lateral part of the corresponding lower laminas. If a disk is present, the nerve root is flattened, displaced posteriorly and exceedingly tense. Usually the lower portion of the root is displaced farther posteriorly by the protruding mass, and therefore it is easier to retract the root slightly upward to remove the herniated portion of the disk with forceps. Only the herniated portion is removed, and there may or may not be more than one fragment. No attempt should be made to curet the space between the bodies of the vertebrae. During the removal every effort should be made to avoid the large extradural veins, and if bleeding is encountered careful hemostasis should be obtained.

SUMMARY

The pathologic anatomy, pathogenesis and the clinical picture, as well as the diagnosis and differential diagnosis of a ruptured cervical disk have been discussed briefly. The type of operation for the removal has been outlined.

Twenty cases of ruptured intervertebral cervical disk have been reported in order to emphasize the symptoms and signs from which a diagnosis may be made clinically.[8] It is noteworthy that 16 of the 20 cases were those of pure root compression and only 4 were those of cord compression. The possibility that the high percentage of root compressions in our series, as compared with those in the older reports of ruptured cervical disk, may be due to earlier recongnition is set forth and the idea entertained that the pathogenesis should be divided at times into three stages: (1) the root compression, (2) the unilateral cord compression with masked root compression and (3) the bilateral cord compression with masked unilateral or bilateral root compression.

8. A complete follow-up is not given, as the interval of time after operation has not been sufficient in all the cases listed.

A history of an initial and of repeated trauma was obtained in the majority of the cases. Twelve of the 20 patients were men in the age group of 36 to 56 years, and 8 patients were women in the age group of 32 to 59 years.

Lumbar puncture was done in 16 instances, manometric readings were made in 15 and total protein contents of the spinal fluid were estimated in 15 of the 20 cases. Myelography was done in all cases of cord compression and in 9 cases of pure root compression.

CONCLUSION

The diagnosis of a ruptured cervical disk is primarily clinical, and the history and subjective complaints are of maximal importance for arriving at an early recognition of the condition. Reproduction of the pain and paresthesias will be possible almost without exception as long as the syndrome is in the stage of root compression. After cord compression has occurred myelography is the method of choice for arriving at a diagnosis of the level and, in many instances, for justifying an etiologic diagnosis.

In the present cases of lateral protrusions the operative results, without exception, have been good. In the cases of cord compression the recovery has not been as spectacular or always complete.

ADDENDUM

Since the submission of this paper 18 more patients with a ruptured cervical disk have been operated on, one of whom had a combined root and cord compression; the remainder had uncomplicated root compressions.

Dr. Barnes Woodhall, Associate Professor of Surgery in Charge of Neurosurgery, Duke University School of Medicine, assisted us by reading and correcting this article

STREPTOMYCIN AND PARACHLOROPHENOL IN SURGICAL INFECTIONS

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THE HISTORY of streptomycin is a story of a planned search for an antibiotic agent capable of bactericidal and bacteriostatic action on gram-negative bacteria, a substance capable of action in the animal body as well as the test tube, with low toxicity and high resistance to inactivation by circulating body fluids and exudates from wounds. In view of the remarkable success obtained, it is natural that streptomycin be given exhaustive and repeated laboratory and clinical trial against the mixed infections seen so frequently in the surgical field.

This study was designed to coordinate the bacteriologic findings in the laboratory with clinical evaluation and tests on a group of burns, ulcers and infected wounds caused by a mixture of bacteria, predominantly gram-negative. Of great importance is the fact that almost all the cultures of material from wounds were made on material from infections clinically resistant to penicillin and sulfonamide drug therapy. It is believed that the percentage of gram-positive bacteria was thereby lessened and that more resistant species were present.

The effect of streptomycin alone and its effect when mixed with agents used commonly for local treatment in surgical infections have been investigated. Sulfanilamide, penicillin, urea, tyrothricin, chlorazodin and parachlorophenol have been given greater or lesser trial when added to streptomycin solutions or ointment bases.

These stubstances were added for the following theoretic considerations: (*a*) that one or more of them might give evidence of stability if mixed with streptomycin; (*b*) that if streptomycin-inactivating substances were found in exudates from wounds there would be less possibility for clinical failure if a second, and unrelated, agent were ready as a block, and (*c*) that the addition of an extra bacteriostatic or bactericidal substance would lessen the prospect of the development of a streptomycin-resistant or drug-resistant bacterium in wounds under

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The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy.

treatment. In the course of investigation parachlorophenol seemed best and was used with streptomycin to the exclusion of the other agents.

Meleney [1] has shown that parachlorophenol in a dosage of 0.25 of 1 per cent may be applied locally in certain infections whose bacteria produce penicillinase and will offset this action, thereby allowing penicillin to act against the associated, more important organisms. Especial reference to this aspect seemed indicated with streptomycin and parachlorophenol.

EXPERIMENTAL DATA

A. Classification of Bacteria Found in Wounds and Their Resistance to Certain Bacteriostatic Agents.—Preliminary experiments were conducted to classify bacteria found in local wounds and to establish the concentrations of separate bacteriostatic agents which were necessary to inhibit the growth of these bacteria in wounds. This was necessary as a basis on which to make up the different admixtures of streptomycin for enhancement and deterioration tests and for clinical usage. In addition it seemed conceivable that one might find a somewhat different group of bacteria in wounds in the tropics and among the Guamanian native population.

Material from thirty different infected wounds, burns, ulcers and impetiginous infections was cultured. From these, fifty-three different species of bacteria were isolated for study. In the main they were gram-negative bacteria from wounds in patients who had received penicillin parenterally and/or sulfadiazine by mouth, but gram-positive diphtheroids and cocci were also present.

Bergey's "Manual of Determinative Bacteriology" (fifth edition, 1939) was used as much as possible in naming unknown strains. It was soon obvious that some species could be typed only as to genus, despite exhaustive metabolic and fermentation tests. The term "Bacterium" is used to cover species of non-spore-forming, rod-shaped bacteria whose position in the system of classification is not definitely established (Breed and Conn [2]).

The exact identification of bacteria present in wounds is often not among the simplest problems of bacteriology, for the multitude of organisms existing in some infected burns, for example, is startling. In addition, an unknown organism may easily be a species or a variant which has never been named or perhaps never adequately described. The authors of Bergey's manual are frank to admit that perhaps the

1. Meleney, F. L.: (*a*) Treatment of Mixed Infections with Penicillin, J. A. M. A. **130**:121-124 (Jan. 19) 1946; (*b*) Penicillin in the Treatment of Established Surgical Infections, Ann. Surg. **124**:962-980 (Nov.) 1946.

2. Breed, R. S., and Conn, H. J.: The Status of Generic Terms Bacterium, Ehrenberg 1828, J. Bact. **31**:517-518 (May) 1936.

TABLE 1.—*List of Bacteria, Classified According to Bergey's "Manual of Determinative Bacteriology" (5th Edition), Isolated from Infected Wounds of Naval Personnel and Guamanian Native Patients Before Treatment with Streptomycin Admixtures (Most Patients Had Received Large Amounts of Penicillin and Sulfonamide Drugs)*

Tubes were read at forty-eight to seventy-two hours for the sensitivity tests. Broth was 1 per cent of Difco's yeast extract in Bacto nutrient broth tubed in 2 cc. amounts, to which 1 cc. of the agent to be tested was added in sterile isotonic solution of sodium chloride. This medium, which was dextrose free and low in phosphate, was considered satisfactory. Waksman and associates [*] have shown that the presence of dextrose, phosphate salt and an acid medium tend to reduce streptomycin's activity. The parachlorophenol solution more concentrated than 1:750 was buffered to p_H 6.8 with sodium hydroxide before it was added to the culture medium. The inoculum was usually 0.01 cc. of a twenty-four hour broth growth of the bacterium to be tested. Tryptose-phosphate broth was usually used for streptomycin titrations with the facultative anaerobes; incubation was then done in an anaerobic jar.

Genus and Species	Total in Genus	Range of and Average Concentration of Agents Needed to Inhibit Growth [*]			
		Streptomycin, Micrograms per Cc. of Broth	Parachlorophenol, Dilution	Chlorazodin, Dilution	Penicillin, Oxford Units per Cc. of Broth
Genus Pseudomonas.....	8	Range, 7 to 500 Average, 100 plus	Range, 1:750 to 1:8,000 Average, 1:1,500	Range, 1:400 to 1:750 Average, 1:500	Average, 2,500 plus
Species aeruginosa (2)					
Species unidentified (3)					
Species incognita (1)					
Species jaegeri (1)					
Species pierantonii (1)					
Genus Micrococcus.....	5	Range, 10:250 Average, 100	Range, 1:800 to 1:4,000 Average, 1:1,000	Average, 1:500 plus	Average, 2,000 plus
Species ureae (3) (gram-negative)					
Species aurantiacus (2)					
Genus Staphylococcus.....	6	Range, 0.5 to 75 Average, 30	Range, 1:800 to 1:3,000 Average, 1:1,200	Average, 1:500	Range, 1:500 Average, 15
Species aureus (3) (coagulase-negative) (2) (coagulase-positive) (1)					
Species citreus (2)					
Species aerogenes (1)					
Genus Diplococcus.....	3	Range, 0.5 to 1.0 Average, 0.6	Range, 1:3,000 to 1:5,000	Average, 1:1,000	Range, 50 plus
Species mucosus (1)					
Species unidentified (2) (facultative anaerobes)					
Genus Streptococcus.....	2	Range, 1 to 15 Average, 7.5	Not tested	Not tested	Not tested
Species faecalis (1)					
Species pyogenes (1) (facultative anaerobe)					
Genus Escherichia.....	8	Range, 0.3 to 50 Average, 15	Range, 1:800 to 1:3,000 Average, 1:2,000	Average, 1:400	Average, 2,500 to 4,000
Species coli (5)					
Species freundii (3)					
Genus Aerobacter.....	2	Average, 40	Average, 1:2,000	Not tested	Average, 2,000
Species aerogenes (3)					
Genus Proteus.....	9	Range, 3 to 15 Average, 7	Range, 1:600 to 1:3,500 Average, 1:800	Average, 1:400	Average, 2,500
Species vulgaris (3)					
Species mirabilis (1)					
Species Morganii (2)					
Species unidentified (3)					
Genus Bacterium.....	4	Range, 1 to 200 Average, 30	Range, 1:800 to 1:4,000 Average, 1:1,500	Not tested	Not tested
Species unidentified (4)					
Genus Achromobacter.....	1	Not tested	Not tested	Not tested	Not tested
Species coccoideum (1)					
Genus Corynebacterium.....	3	Range, 1 to 250 Average, 35	Range, 1:1,000 to 1:2,000 Average, 1:1,250	Not tested	Average, 1,000
Species xerose (1)					
Species ulcerogenes (1)					
Species unidentified (1)					
Genus Chromobacterium.....	2	Average, 50	Average, 1:1,000	Average, 1:400	3,000
Species lanthinum (1)					
Species unidentified (1)					

[*] There was a total of fifty-three strains.

description and name of a bacterium may have been overlooked, for the number of species described in the literature is so great that no person can know all the species. Thus no apology is offered for the number of species unidentified within the genera in table 1.

It is of real worth to have an enriched medium which will support the growth of fastidious bacteria, aerobically and anaerobically, and yet suppress the "spreader" colonies such as Proteus, which overgrow and suppress the coexisting species. Of value here has been a blood agar plate to which 5 per cent alcohol has been added. First described by Floyd,[3] this medium, if used within five days of being made up, will allow colonies to be picked and identified forty-eight hours or longer after inoculation, even in the presence of predominant Proteus growth.

Material from wounds was cultured by the removal of bits of the edge of the skin if there was any suggestion of erythema of the tissues at this site or evidence of advancing infection. This tissue was triturated in sterile isotonic solution of sodium chloride, and aerobic and anaerobic thioglycollate cultures were made from the suspension. It will be noted in table 1 that two strains of Diplococcus and one strain of Streptococcus were facultative anaerobes, but most of the bacteria grew well aerobically. These results with anaerobic cultures, combined with the clinical appearance of most of the wounds, would seem to indicate that the tabulated strains did indeed represent the virulent organisms and not just surface contaminants which were responsible for the continued presence of infection in the tissue.

Table 1 shows the fifty-eight species of bacteria in wounds isolated, studied and typed. Also indicated are the average sensitivity and the range of sensitivity within each bacterial genus to streptomycin, parachlorophenol, chlorazodin and penicillin. It will be noted that the four genera which had species most resistant to streptomycin were Pseudomonas, Micrococcus, Corynebacterium and Bacterium. Rare strains showed growth after forty-eight hours in as much as 250 to 500 micrograms of streptomycin per cubic centimeter of medium with a moderate inoculum. However, in view of the slight but definite effect on cellular growth of concentrations over 200 micrograms (Howes[4] and Heilman[5]), it was decided not to go higher than 500 micrograms per cubic centimeter for clinical use. Dilution by exudates from wounds would, of course, alter this concentration.

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3. Floyd, T. M., and Dack, G. M.: Isolation of Bacterium Necrophorum in Presence of Proteus, J. Infect. Dis. **64**:269-272 (May-June) 1939.

4. Howes, E. L., cited by Waksman, S. A., and Schatz, A.: Streptomycin: Origin, Nature and Properties, J. Am. Pharm. A. (Scient. Ed.) **34**:273-291 (Nov.) 1945.

5. Heilman, D. H.: Cytotoxicity of Streptomycin and Streptothricin, Proc. Soc. Exper. Biol. & Med. **60**:365-367 (Dec.) 1945.

Parachlorophenol was effective against all these organisms in a 1:500 (0.2 per cent) solution, and usually a 1:1,000 dilution showed complete inhibition of bacterial growth in vitro. This substance was considered more effective in a 1:500 dilution against the bacteria from wounds isolated and tested in vitro than chlorazodin, penicillin and sulfanilamide in concentrations usually used locally.

Tests were then made to determine the stability of mixtures of streptomycin and parachlorophenol and of streptomycin mixed with other bacteriostatic substances. A strain of Escherichia freudii and of Proteus morganii being used as test organisms, it was found that little or no real deterioration of bactericidal titer occurred in streptomycin admixed with parachlorophenol after ten days at room temperature. There was a slight loss of titer after ten days at 37 C. After being autoclaved fifteen minutes at 20 pounds (9 Kg.) of pressure, this streptomycin admixture showed a loss of titer only from 0.5 to 40 micrograms per cubic centimeter.

For practical purposes streptomycin can then be mixed with any of the aforementioned bacteriostatic agents and if stored at 5 C. and used within one week will not suffer material loss. In especial reference to parachlorophenol it would seem that it is compatible with streptomycin and superior to these other agents as determined by in vitro tests.

In order to test this hypothesis further, material from eighteen wounds was cultured, all of which had two or more bacterial species in symbiosis. The predominant organism as determined by blood agar streaking was Staphylococcus aureus in 4, Proteus in 4, Escherichia coli in 3, Chromobacterium in 2, Micrococcus in 2, Pseudomonas in 2 and a diphtheroid in 1. In every case a mixture of streptomycin (500 micrograms per cubic centimeter) in parachlorophenol (1:500) and a 1:3 and 1:5 dilution of this in isotonic solution of sodium chloride were sufficient to suppress growth in nutrient broth for seventy-two hours. A 0.01 cc. inoculum of a twenty-four hour broth culture was used.

Meleney and associates[1a] reported Howes's statement that parachlorophenol in the concentration 1:500 (0.2 per cent) has no appreciable effect on the healing of experimental wounds in rabbits. The absence of cytotoxicity of this concentration, along with its powerful bacteriostatic effect on gram-negative bacteria (table 1) and its stability when mixed with streptomycin (mentioned previously), led me to confine my clinical trials to streptomycin 500 micrograms per cubic centimeter in parachlorophenol 0.2 per cent. However, since the halogenated phenols are readily absorbed, the possibility of remote systemic toxic effect from prolonged local application must be borne in mind. In addition it would seem unwise to inject parachlorophenol into tissues surrounding a chronic resistant ulcer—a procedure which with penicillin and streptomycin is sometimes of real value and without harm. Parachlorophenol, however,

is useful as an agent for topical application and, as Meleney [1] showed, is a good adjuvant with penicillin in some instances.

B. The Local Use of Combined Streptomycin and Parachlorophenol in Infected Wounds, Burns, Ulcers and Cutaneous Lesions.—(*a*) Combination of Streptomycin and Parachlorophenol in Liquid Phase: Streptomycin (500 micrograms per cubic centimeter) is readily soluble in water. Parachlorophenol is a somewhat oily liquid with a specific gravity of 1.31. A 1:500 dilution (by weight) is soluble and has a pleasant phenolic odor, which is of value as a deodorant in some wounds. Parachlorophenol is moderately acid, and because the optimal activity of streptomycin is at p_H 9 (Waksman and colleagues [6]) it was thought best to adjust the p_H of the streptomycin-parachlorophenol mixture at 7.5, easily handled by the tissues.

(*b*) Use of Several Different Ointment Bases: Ointment base I was composed of cetyl alcohol 10.0 per cent and water 79.0 per cent. Ointment base II contained sodium benzoate 0.2 per cent, stearic acid 10.0 per cent, glycerol monostearate 5.0 per cent, glycerol laurate 5.0 per cent, glycerin 10.0 per cent and distilled water 69.8 per cent.

Ointment base III contained carbowax 4,000 (45 per cent) and propylene glycol (55 per cent) by weight.

In the tropics it was found desirable to combine these bases with an equal part of cold cream base whenever they were incorporated with sterile gauze for use in burns. This procedure seemed to allow the ointment to stick to the gauze longer and therefore to remain longer in contact with the burned area. At the same time it should retain enough of the desirable water-soluble property for the release of streptomycin and parachlorophenol to the tissues. These agents were homogenized with the base in question so that streptomycin (500 micrograms) and parachlorophenol (0.2 per cent) were in each gram of ointment.

Insufficient clinical trial was performed, and therefore no significant comparison could be made between these bases. All of them seemed to be satisfactory and would theoretically be superior to hydrous wool fat, petrolatum or greases for incorporation of antibiotic agents, so far as they release the bacteriostatic agent to the tissues more readily.

All ointments containing streptomycin-parachlorophenol were tested by rubbing them well into the intact skin of the anterior parts of the forearms of 15 normal human volunteers. In no case was any erythema or reaction noted.

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6. Waksman, S. A.; Bugie, E., and Schatz, A.: Isolation of Antibiotic Substances from Soil Micro-Organisms with Special Reference to Streptothricin and Streptomycin (Mayo Foundation Lecture), Proc. Staff Meet., Mayo Clin. **19**:537-548 (Nov. 15) 1944.

The addition of cold cream to the ointment seemed to diminish the sensation of slight burning of which some burned patients complained when the ointment gauze was first applied. In 1 patient with a chronic "tropical" ulcer of the leg the ointment briefly accentuated an already present erythema at the edge of the lesion. Otherwise there was no suggestion of toxicity.

C. Treatment in Clinical Cases.—Table 2 summarizes the significant data obtained in treatment of 10 patients with infected burns, ulcers and wounds. During treatment frequent cultures were made, and they were carefully observed from the clinical standpoint.

Of particular interest, but not necessarily invalidating the use of streptomycin-parachlorophenol, was the development of streptomycin-resistant bacteria in some treated wounds. In 2 of the 10 cases such a situation developed, and in both of these it was a bacterium of the Pseudomonas genus which became resistant. In case 3 the original species of Pseudomonas isolated before treatment was inhibited by 100 micrograms of streptomycin per cubic centimeter of broth and by 1:2,500 parachlorophenol. Under treatment it became resistant to as high as 18,000 micrograms per cubic centimeter but was not able to grow in parachlorophenol 1:500 or 1:2,500. This illustrates the development of resistance under treatment to one but not to another agent which has been given simultaneously. Thus, in this instance the theoretic advantage of one agent acting as a block to growth, in case of resistance acquired against another agent, was shown to have practical importance. It will be remembered that it was in part for this theoretic reason that streptomycin was admixed with parachlorophenol originally in the in vitro tests.

In case 9 the bacterium became insensitive to 10,000 micrograms of streptomycin per cubic centimeter but was susceptible to 1:500 parachlorophenol.

In a few instances there remained the possibility that prolonged use of the ointment gauze had retarded epithelization. However, having investigated such a small group of patients, one is not justified in commenting, other than to state it as a potential danger.

In general the combined use of streptomycin and parachlorophenol was found to be of value in some cases for the local treatment of the mixed infections seen in surgery. As no attempt was made to compare it to tyrothricin (Kozoll [7]) or to streptomycin and Sulfamylon (para-[aminomethyl]-benzene sulfonamide) (Howes [8]) no statements relative

7. Kozoll, D. D.; Meyer, K. A.; Hoffman, W. S., and Levine, S.: The Use of Tyrothricin in Surgical Infections, Surg., Gynec. & Obst. **83**:323-342 (Sept.) 1946.

8. Howes, E. L.: Prevention of Wound Infection by the Injection of Nontoxic Antibacterial Substances, Ann. Surg. **124**:268-276 (Aug.) 1946.

TABLE 2.—*Clinical Cases in Which Treatment Was Done with Streptomycin-Parachlorophenol*

Patient	Age, Yr.	Sex	Diagnosis	Streptomycin and Parachlorophenol Used as	Duration of Treatment	Earlier Treatment with Penicillin and Sulfonamide Drugs	Change in Bacterial Flora with Treatment	Comment
1. F. D.	33	Male	Appendical abscess and an abscess in abdominal wall postoperatively; treated for the latter	Solution for irrigation and as ointment gauze for packing	2 wk.	Yes, both in large amounts for 4 wk. (parenteral and oral, not local)	At beginning: pure growth of a facultative anaerobic diplococcus; after treatment: occasional Proteus	Rapid and gratifying improvement, which kept the abscess cavity clean until early and complete healing resulted
2. C. P.	19	Male	Second degree burns of right leg, 8 by 10 cm.	Ointment gauze	6 days	Penicillin only 100,000 units parenterally and penicillin compresses for 3 days	At beginning: (*a*) Esch. coli, small numbers and (*b*) Chromobacterium; after treatment: cultures sterile or occasional Micrococcus	Appearance of wound improved; (*a*) less exudate, (*b*) felt better to patient and (*c*) epithelization more rapid
3. H. M.	13	Male	Extensive 2d and 3d degree burns of legs from gasoline	Wet compresses and as ointment gauze	30 days	Yes, both in large amounts for 3 and 6 wk. (parenteral and oral not local)	At beginning: rampant, foul-smelling mixed infection with: (*a*) P. vulgaris, (*b*) Esch. coli, (*c*) Chromobacterium and (*d*) Micrococcus; after streptomycin treatment: resistant strain of (*a*) Pseudomonas and (*b*) occasional Proteus	Great clinical improvement in first week of treatment: (1) temperature fall and (2) burns improved in appearance and lost foul odor and discharge; last week of treatment showed little advantage over petrolatum gauze; greenish pus
4. J. R.	3	Male	Extensive 2d and 3d degree burns of arms and face	Ointment gauze	3 wk.	Yes, both for 2 wk. prior to streptomycin	At beginning: (*a*) P. morganii, (*b*) diphtheroid and (*c*) Bacterium genus; after streptomycin treatment; gram-negative micrococci	The effect was not impressive; healing was slow; petrolatum gauze after 3 wk. of treatment
5. E. M.	43	Male	"Tropical" ulcer on leg; at least partly explained by inadequate venous drainage	Ointment gauze and wet compresses; local injections of streptomycin alone	3½ wk.	Large amounts of penicillin; he was considered sensitive to sulfadiazine	At beginning: (1) Esch. freundii, (2) C. xerose and (3) Staph. aureus; after streptomycin treatment: occasionally an unidentified diphtheroid	The infectious element of this ulcer was easily controlled by treatment; healing was slow but helped by Ace bandage and rest
6. T. S.	22	Male	Chronic leg ulcer of 6 mo. duration; had been excessively treated with mercurials; 8 cm. in diameter; negative Kahn reaction	Ointment gauze; local injections of streptomycin alone	3 wk.	Had had large amount of both drugs; recent penicillin compresses	At beginning: (1) Streptobacillus, (2) P. morganii; after streptomycin treatment: repeatedly sterile cultures	The infectious element was easily controlled; this ulcer had a fibrous base and underlying periostitis; definite slow improvement
7. I. B.	21	Male	Chronic leg ulcer of 6 mo. duration; 3 cm. in diameter	Ointment	2 wk.	Yes, had had	At beginning: (1) Ps. aeruginosa; after treatment: occasional Micrococcus	Improvement was striking
8. P. D.	24	Male	Excised pilonidal sinus with primary closure; reopened inferior aspect of wound after infection occurred	Ointment gauze after a few days of irrigation	3 wk.	No	At beginning: (1) Esch. coli, (2) Staph. aureus, (3) P. mirabilis; after treatment: cultures usually sterile; occasionally A. aerogenes	Healing was rapid; discharge from the wound changed from large amounts to scant
9. P. R.	29	Male	Surface infection of guillotined stump of left leg	Wet compresses and ointment gauze	2 wk.	Yes, both given in large amounts	At beginning: (1) C. ulcerogenes and (2) Str. pyogenes; after streptomycin treatment: (1) Pseudomonas (resistant to 10,000 micrograms per cc. of streptomycin)	Difficult to assess the value here; further surgical treatment was necessary to open subcutaneous pockets of pus; agent seemed effective when it reached the bacteria
10. R. H.	19	Male	Chemical burns of scrotum, infected with great exudation	Wet compresses and ointment alone	7 days	No	At beginning: (1) Bacterium genus and (2) Esch. coli; after streptomycin treatment: sterile	Rapid healing and definite, quick improvement clinically

to these agents can be made. There would seem to be a few practical points favoring Sulfamylon over parachlorophenol so far as its range of activity against most strains of streptococci is excellent and its toxicity is less than parachlorophenol.

It may well be that the main indication for combined use of streptomycin-parachlorophenol would be for topical application on a badly infected burn, abscess or wound resistant to penicillin and sulfonamide drugs, and then its use would be for a matter of days only, because of the danger of acquired resistance to streptomycin. Of equal importance may be its short term use as a local agent with penicillin given intramuscularly in the presence of overwhelming mixed infections associated with widespread burns or large, deep abscesses.

However, in recent investigations, Herrell and Nichols,[9] Pulaski [10] and others have indicated that in the presence of inadequate dosage of streptomycin or even in the presence of large amounts of it some pathogenic bacteria may develop resistance to this antibiotic in a short time. In some respects, then, these findings dampen the enthusiasm for the prolonged or inadequate use of streptomycin on wounds. There is no evidence from my experimental work, however, that streptomycin resistance develops against an organism ordinarily responsible for bacteremia or serious systemic infection, for Pseudomonas is not a usual invader of the blood stream. In addition I believe that its bactericidal effect on such a wide variety of gram-negative organisms, its low toxicity and its ability, if needed in an invasive infection, to be injected around and into a wound, which is probably unwise with parachlorophenol, indicate the use of streptomycin in certain infections as a local agent. Used with parachlorophenol there may be less chance for resistant strains to develop against streptomycin. Further investigations are warranted, and no claim is made that this suggestion is always true or conclusive.

The decision to use streptomycin, then, must weigh the dangers of its inducing acquired bacterial resistance against the advantages it offers in certain cases of gram-negative or mixed bacterial infections seen in surgery. One of its main advantages is its usefulness for local injection into and around the edge of the wound in chronic or advancing lesions if penicillin seems ineffective in such an infection.

The criticism which may be levied against streptomycin on the basis of the "acquired resistance" property applies also to other agents used locally on wounds, although probably to a lesser extent. Sulfonamide drugs, some antibiotics and inorganic and organic agents all induce

9. Herrell, W. E., and Nichols, D. R.: Clinical Use of Streptomycin, Proc. Staff Meet., Mayo Clin. **20**:449-462 (Nov. 28) 1945.

10. Pulaski, E. J.: Streptomycin in Surgical Infections, Ann. Surg. **124**:392-401 (Aug.) 1946.

bacterial resistance, in greater or lesser extent, following prolonged use. Gram-negative bacteria as a group are more hardy, resistant bacteria than gram-positive bacteria (Dubos[11]), and it is to be expected that the gram-negative group would overcome more quickly any obstacle, whether antibiotic or otherwise, which inhibits their metabolism in general or their enzymatic, intermediate chemical processes. Streptomycin has proved effective against many difficult therapeutic problems in gram-negative bacterial infections, and while it is by no means a perfect agent, it has its useful place in the surgical armamentarium until something superior to it is discovered.

COMMENT

Again and again one is impressed in such a study with observations which illustrate the multiplicity of factors, besides simple bacterial infection, which may prevent or retard healing in infected lesions. Poor blood supply or circulatory stasis, minute or large foreign bodies, inadequate nutritional status or blood dyscrasias, hypersensitivity to drugs or food, inadequate drainage, overactive fibrosis or structural changes in the wound itself are some among many of these important factors. It is to be emphasized that no treatment, local or systemic, with antibiotics or antibacterial agents can be successful unless one is constantly on the alert to counteract or prevent these aforementioned conditions from obtaining the upper hand. In many cases, it is of far more importance to alleviate such an undesirable condition than it is to change the species of bacteria in a wound, or even to keep it reasonably sterile. Antibiotics are no substitute for good surgical principles. In view of much recent work with these agents, it seems wise to emphasize this repeatedly.

The local use of agents designed for their effect on bacteria present in wounds meets with other problems, among which are the dilution of the agent by exudate from the wound and the mechanical failure to get the agent to the bacteria which lie deeper in the tissues than on the surface. Intelligent treatment will sometimes dictate such procedures as trimming off exuberant granulation tissues, compressing or débriding eschars and crusts and in some cases revising the wound surgically. As an example of the latter, fibrotic chronic ulcers of the lower leg may respond to excision, local compressing with streptomycin and grafting. In some resistant infections, as indicated before, local injection of streptomycin or penicillin into the periphery of the infection may succeed in benefiting the lesion by establishing a high concentration of antibiotic in the area in which it will do the most good.

11. Dubos, R. J.: The Bacterial Cell in Its Relation to Problems of Virulence, Immunity and Chemotherapy, Harvard Monograph in Medicine and Public Health, Cambridge, Mass., Harvard University Press, 1945.

Dr. Meleney, of New York city, has been a leader in the investigation of surgical infections, and the impact of his thinking is acknowledged. One is too often a spectator at the "dumping" of some agent on or in a wound or sinus whereby the corpsman or doctor is obviously unaware of the agent's toxicity or its inability to act on or reach the bacteria responsible for the infection. It is hoped that the somewhat optimistic findings of this article will not increase the incidence of such irrational treatment.

So far as there is yet much to learn about antibiotics in relation to the mixed and symbiotic bacterial infections seen so commonly in surgery and so far as there is no simple correlation between in vitro and in vivo results with streptomycin, it would seem advisable to defer optimism until further clinical studies with this antibiotic are made.

SUMMARY

1. Bacteria found in burns, ulcers and wounds, generally resistant to sulfonamide drugs and penicillin, were classified and tested for sensitivity to streptomycin, parachlorophenol, chlorazodin and penicillin.

2. A mixture of streptomycin 500 micrograms per cubic centimeter and parachlorophenol 0.2 per cent was found adequate for the suppression of growth of all bacteria in vitro before treatment and preferable to other agents tested. The stability of this mixture is adequate for practical purposes.

3. In 10 cases infected burns, ulcers and wounds found in Guamanian natives and United States Naval personnel were treated locally with the streptomycin-parachlorophenol mixture as a solution or incorporated in various ointment bases, with generally good results.

4. Streptomycin-resistant strains of the genus Pseudomonas developed in some instances in vivo after treatment. The suggestion is made that perhaps local treatment with streptomycin should not be for long periods. The danger of development of resistant strains, although apparently real and possibly common with prolonged use, should not contraindicate use of streptomycin in selected cases.

5. The injection of streptomycin, 200 micrograms per cubic centimeter, into the periphery of some wounds seemed of benefit.

6. It should be emphasized that these agents are only adjuvants and cannot replace good surgical principles.

Lieutenant T. M. Floyd, H(S), U.S.N.R.; Chief Pharmacist's Mates O. L. Selman, K. P. Egner and R. H. St. John, and Pharmacist's Mates Third Class C. R. Poore and Theodore Stone gave assistance in this work. Chemical preparation of parachlorophenol was accomplished by Ensign L. E. Miller, H(S), U.S.N.R.

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PROGRESS IN ORTHOPEDIC SURGERY FOR 1945

A Review Prepared by an Editorial Board of the American Academy of Orthopaedic Surgeons

VII. TUBERCULOSIS OF BONES AND JOINTS

Prepared by

ALAN DeFOREST SMITH, M.D.

NEW YORK

(Continued from Page 219)

LEWIS [156] expresses the opinion that Phemister's criteria, used in distinguishing tuberculous and nontuberculous (pyogenic or suppurative) arthritis, are of such importance as to warrant restatement.

In pyogenic (nontuberculous) arthritis, Phemister states that the articular cartilage is destroyed first at the points of contact and pressure and necrotic material is rapidly removed with the assistance of proteolytic ferments. However, the articular cartilage is not destroyed first in tuberculous arthritis but is protected at points of contact and pressure, the earliest destruction being peripheral, where tuberculous granulations can grow onto and remove the cartilage. The proteolytic ferments are not present as in pyogenic arthritis, so that masses of dead cartilage may persist for months or years. Also, the first evidence of destruction of bone is usually peripheral, where there has been absorption by the tuberculous granulations.

Thus, in terms of roentgenology, the joint space is narrowed early in pyogenic arthritis, while the joint space is preserved in tuberculous arthritis for months or years.

Added distinguishing characteristics are the following ones: 1. Severe osteoporosis is present about the joint in acute suppurative arthritis as result of acute congestion. This is not seen in tuberculous arthritis. 2. Repair and ankylosis are more the rule in pyogenic than in tuberculous arthritis. 3. Adjacent muscular atrophy is seen in tuberculous arthritis but not in pyogenic joint disease.

[ED. NOTE (A. D. S.).—Thinning of the joint or cartilage space has been seen regularly in roentgenograms at an early stage of tuberculosis of the joint in cases in which the diagnosis subsequently was proved at operation. We have come to regard it as one of the early evidences of tuberculosis.]

156. Lewis, R. W.: Differential Diagnosis of Tuberculosis in Joints of Extremities, Am. J. Roentgenol. **54**:329-337 (Oct.) 1945.

Wood and Wilkinson [157] emphasize the importance of lateral roentgenography in the early diagnosis of tuberculosis of the hip. Roentgenography provides a means of tracing the different phases of the disease, that is, the destructive and the reparative stages. The roentgenologic changes appear late in the disease of the hip as contrasted to pulmonary tuberculosis, and this is a handicap in the diagnosis.

As in other inflammatory disease of bone, the earliest change in tuberculosis is rarefaction due to hyperemia. Later, the articular cartilage becomes absorbed, a pannus spreading over it from the periphery. The edge of the cartilage is absorbed first. Subsequently the joint becomes narrower than normal, although initially the joint may be distended by fluid. In another type of disease there is cavitation in the bone close to the articular margins in the early stage, with the joint space being affected later.

The lateral roentgenograms are taken with the patient lying on the affected side. The opposite leg is drawn backward, and the pelvis is rotated so as to form an angle of 65 degrees with the horizontal. The anterior-posterior roentgenograms are taken in the usual manner. The lateral roentgenogram provides a more extensive view of the hip joint and also assists in the localization of tuberculous lesions.

Protar [158] discusses the similarity in the roentgenologic findings between the caries sicca type of tuberculosis of the shoulder and epiphysitis of the proximal humeral epiphysis. He states that epiphysitis of the proximal humeral epiphysis is similar to Legg-Calvé-Perthe disease of the hip and that the roentgenologic differences are due to the fact that the hip is a weight-bearing joint and thus subjected to forces different from those of the shoulder.

Seligson [159] states that there has been little acceptance in America of the fact that the numerous extrapulmonary inflammatory and degenerative lesions described by Poncet and Leriche belong to the clinical picture of tuberculosis. The wide variety of manifestations, including transitory inflammatory changes in joints and serous cavities which they described, have not been proved tuberculous by routine bacteriologic and pathologic tests but Poncet and his disciples were of the opinion that bacillary toxins rather than the tubercle bacillus cause tuberculous rheumatism.

157. Wood, F. G., and Wilkinson, M. C.: X-Ray Examination of Hip-Joint in Tuberculous Disease with Special Reference to Localization of Cavities and Tuberculous Foci, Brit. J. Radiol. **18**:332-334 (Oct.) 1945.

158. Willemin, F., and Protar, M.: Superior Humeral Epiphysitis: Differential Diagnosis of Volkmann's Dry Caries; Relation to Pathogenesis of Recurrent Luxation of Shoulder, J. de radiol. et d'électrol. **26**:64-66, 1944-1945.

159. Seligson, F.: Poncet's Disease: Clinical Observations on Inflammatory and Degenerative Joint Reactions in Tuberculosis, Am. Rev. Tuberc. **52**:463-473 (Dec.) 1945.

There are some observations that could give additional weight to Poncet's observations. The work of Loewenstein and others demonstrated tubercule bacilli in the circulation in various conditions (this work has found little support). Rich compared the effects of a striking systemic reaction in tuberculosis (fever, malaise, headache, anorexia, joint pains, backache and prostration) with those of anaphylactic "serum sickness." Klinge was able to prove that the same organism could produce septic and purulent inflammation at one time and allergic reactions distant from the original focus of infection at other times. (Frequently even inoculations of guinea pigs with pleural fluid give negative reactions, but the consequent clinical course shows the development of tuberculosis.) Neumann speaks of "beginning tuberculosis hiding behind rheumatism." Certain other facts could support the conception —the arthropathies following a tuberculin test or following an "ophthalmo-reaction" and the temporal relation between the arthropathies and the pulmonary flare-ups.

The author summarizes 8 cases which could be classified within the group mentioned by Poncet. The importance of serous effusion and rheumatic manifestations in the joints in recognition of cases hitherto not regarded as tuberculosis is emphasized.

Schumann [160] states that clinical, laboratory and roentgenologic examination may fail in diagnosis of tuberculosis of the knee joint. Of 23 cases of chronic hydrops, the conditions in 8 were clinically diagnosed as tuberculosis. In 6 of these the diagnoses were confirmed histologically. In the remaining 15 cases, histologic study revealed tuberculosis present in 5 and absent in 10. All cases of chronic hydrops of knee, even with a history of trauma, should be suspected of tuberculosis.

In the course of observations made on mounted skeletons, Kaplan [161] noticed that variation in the mamillary tubercle was found on the twelfth dorsal vertebra when it was compared with other vertebra. The author discusses nomenclature of the transverse and related processes of the eleventh and twelfth thoracic and first lumbar vertebrae.

In examination of spines of human beings it was found that the mamillary process of the twelfth thoracic vertebrae was situated behind the superior articular process and separated from the latter by a deep groove. The relationship between the superior articular process and the mamillary tubercle on the twelfth thoracic vertebrae differed in that the mamillary process is smaller and placed farther back of the superior articular process. Further, there is no deep groove between them. The

160. Schumann, H. D.: Exploratory Excision of Capsule in Suspected Tuberculosis: Problem of Trauma in Relation to Tuberculosis, Chirurg **16**:27 (Jan.) 1944.

161. Kaplan, E. B.: The Surgical and Anatomic Significance of the Mamillary Tubercle of the Last Thoracic Vertebra, Surgery **17**:17-92 (Jan.) 1945.

mamillary tubercle of the first lumbar vertebra is placed lateral to the superior articular process and is entirely unlike that of the eleventh and twelfth thoracic vertebrae. A numerical relationship between the heights of the superior articular process and the mamillary tubercle of the twelfth thoracic vertebra was found to be 25 : 17.

Spines of a number of other animals were examined, and it was found that the mamillary process was present in all, the relationship in size between the superior articular process and the mamillary tubercle being variable.

In gibbons, however, the mamillary process on the thirteenth thoracic vertebra (the last thoracic vertebra in the gibbon) was found to be similar to that in human beings. It is of interest that gibbons are the only other animals which assume the upright biped position.

The author points out that the semispinalis and the multifidus muscles originate from the mamillary process of the twelfth thoracic vertebra and insert into the spinous processes of the ninth and tenth thoracic vertebrae. The aforementioned muscles together with the rotator muscles probably form a strong group, which plays an important role in this area of functional transition.

The author states that the mamillary tubercle has a surgical significance in that it serves to identify the twelfth thoracic vertebra. Further, since the mamillary process, viewed from behind, covers the articulation between the superior process of the twelfth and the inferior process of the eleventh thoracic vertebrae, it must be removed in order to expose the articulation just mentioned when a Hibbs fusion is done.

An interesting report [162] from the Massachusetts General Hospital presents a 64 year old man who was admitted with a history of sudden onset of pain in the lower part of the thoracic portion of the spine, which radiated anteriorly. This subsided over a period of weeks, but he progressively lost strength in his lower extremities and became unable to walk. Roentgenologic examination showed decalcification of the left pedicle of the sixth thoracic vertebra, and two weeks later the pedicle was partially destroyed and there was a defect of the right lateral portion of the body of this vertebra and considerable narrowing of the fifth and sixth dorsal disks. Spinal puncture revealed complete cord block, and the spinal fluid protein content was 114 mg. per hundred cubic centimeters. Physical examination showed complete paralysis of the legs, with absence of tendon reflexes and a negative Babinski sign.

The case was discussed by Dr. Arthur L. Watkins and his staff. The diagnosis decided on was compression of the spinal cord by a tumor at the level of the sixth dorsal vertebra. Epidural sarcoma, meningioma,

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162. Tuberculosis of Vertebra with Extension to Dura, Massachusetts General Hospital Case 31352, New England J. Med. **233**:281-283 (Aug. 30) 1945.

neurofibroma or metastatic carcinoma were considered most likely diagnoses. About tuberculosis, Dr. Watkins stated that "one would not expect to have such a rapid progression of neurologic signs without evidence of more extensive bone destruction, possibly with soft-tissue changes, than is apparent in this case."

An exploratory laminectomy was performed, and reddish tissue was found under the sixth dorsal nerve root outside the dura. This tissue extended alongside the nerve root through the foramen. Microscopic examination showed the mass to be tuberculous.

Ahlberg [163] reports 131 patients with tuberculosis of the wrist who have been under treatment in the Apelviken Seashore Sanatorium in the period from 1928 to 1940. This number makes 2.2 per cent of the total material on tuberculosis of the bones and joints. Operative treatment was employed in 46; 77 patients were given conservative treatment.

Tuberculosis elsewhere in the body was ascertained in 58 of the patients (44.2 per cent). Forty patients (30.5 per cent) presented tuberculosis of the bones or joints elsewhere, outside the wrist. In 49 patients (37.4 per cent) tuberculosis of the wrist was the only localization of tuberculosis ascertained. Forty-eight (36.6 per cent) of the patients demonstrated tuberculous changes in the lungs during or prior to the development of tuberculosis of the wrist, a number which is probably too low. The right hand was attacked in 65 patients and the left in 64. In 2 patients the lesion was bilateral. In 24 patients the illness lasted less than three months before their admission to the hospital; in 55 the process had lasted over twelve months.

The author emphasizes that in conservative treatment it is highly important that the hand be immobilized in dorsal flexion of 45 degrees from the beginning.

Among the cases of operation in this report, partial resection was done in 2 cases, with a favorable result. In all the other cases of operation total resection was performed. Among the cases of operation healing was obtained primarily in 36 (76.6 per cent). A fistula was formed in 7 cases. On an average, the after-treatment lasted five months.

Tuberculosis of Bones and Joints.—Papers continue to appear regarding the therapeutic value of various sulfones and other drugs in experimental tuberculosis [164] and in human tuberculosis of a predominantly

163. Ahlberg, A.: Tuberculosis of Wrist: Therapy and Results, Acta orthop. Scandinav. **14**:153-182, 1943.

164. Tytler, W. H.: Sulfone Compounds in Chemotherapy of Tuberculosis: Review of Experimental Results and Pharmacological Data, Tubercle **25**:95 (Nov.-Dec.) 1944; **26**:23 (Jan.-Feb.) 1945. Melville, K. I., and Stehle, R. L.: Chemotherapy in Experimental Tuberculosis (Using Aminobenzene, Sulfonamide and Sulfone Derivatives), Canad. J. Research, Sect. E. **22**:95-121 (Dec.) 1944.

(Footnote continued on next page)

pulmonary type, but the note of optimism for a dramatically successful treatment of human tuberculosis by any of these presently known agents is lacking. They indicate the need of search for drugs of more powerful action and lower toxicity. Streptomycin appears to give promise of considerable usefulness in some types of tuberculosis infection.

The pronounced inhibiting action of diasone (disodium formaldehyde sulfoxylate diaminodiphenylsulfone) on the acute form of primary tuberculosis infection in guinea pigs has been confirmed by Giroux,[165] but he found the action much less striking in the caseous form of pulmonary tuberculosis developing after reinfection.

Petter's [166] general review of his experience with administration of diasone to 170 patients in seventeen months does not indicate that the compound will cure pulmonary tuberculosis or close large cavities. Although the compound exhibited toxic manifestations in the majority of patients, most reactions were only mild. His impression is that changes for the better in certain predominantly exudative lesions have occurred generally faster and in greater degree than would be expected of conventional therapy alone. Fibroid lesions did not respond well. Observed data in the few patients studied with bone, renal, peritoneal, glandular and pleural lesions were almost entirely favorable. Eighty per cent of a small group with genitourinary and osseous tuberculosis (all but 2 patients) showed symptomatic improvement as well as roentgenographic and laboratory evidence of control. Petter feels that diasone judiciously administered is an adjunct to the conventional treatment of tuberculosis and that investigation with the drug should be continued.

Streptomycin and six other antibiotic substances were tested by Schatz and Waksman [167] for their bacteriostatic effect in vitro against Mycobacterium tuberculosis. Streptomycin, because of its high activity and lower toxicity, appeared to be the most promising of these agents for practical use against the human tubercle bacillus. It was also highly effective in vitro against Erysipelothrix and Actinomyces.

McBurney, R.; Cason, L., and Searcy, H. B.: Effect of Oral Administration of Thymol on Experimentally Induced Tuberculosis, J. Lab. & Clin. Med. **30**:32-38 (Jan.) 1945. Feldman, W. H., and Hinshaw, H. C.: Effects of 4-Amino-4'-Propylaminodiphenyl Sulfone on Experimental Tuberculosis, Proc. Staff Meet., Mayo Clin. **20**:161-166 (May 30) 1945.

165. Giroux, M.: Diasone (Diaminodiphenylsulfone Derivative) Therapy of Experimental Tuberculosis of Guinea Pig: Primary Infection and Reinfection, Laval méd. **9**:788-803 (Dec.) 1944.

166. Petter, C. K.: Experiences with Diasone in Clinical Tuberculosis, Tuberculology **7**:67-72 (Jan.) 1945.

167. Schatz, A., and Waksman, S. A.: Effect of Streptomycin and Other Antibiotic Substances upon Mycobacterium Tuberculosis and Related Organisms. Proc. Soc. Exper. Biol. & Med. **57**:244-248 (Nov.) 1944.

Five highly virulent human type strains of Myco. tuberculosis were found by Youmans [168] to be equally sensitive to streptomycin in vitro. The lowest bacteriostatic concentration was between 0.095 and 0.78 units per cubic centimeter. Within wide limits, the bacteriostatic activity of streptomycin for tubercle bacilli was not significantly affected by the number of organisms or by the presence of human plasma. The bactericidal concentration of streptomycin for 0.1 mg. of virulent human tubercle bacilli was in excess of 50 units per cubic centimeter.

Feldman and Hinshaw [169] and Feldman, Hinshaw and Mann [170] found streptomycin to be well tolerated by guinea pigs and capable, under the several conditions imposed, of exerting in guinea pigs a striking suppressive effect on the pathogenic proclivities of two human strains of Myco. tuberculosis. At the end of the most elaborate experiment, in which treatment was started forty-eight days after inoculation and was continued for one hundred and sixty-six days, 52 per cent of the treated animals exhibited no tuberculosis grossly or microscopically and 39 per cent of the treated animals living when the experiment was terminated gave a negative reaction to tuberculin. These results seem to indicate that streptomycin is the most effective in vitro tuberculochemotherapeutic agent at present known.

Youmans and McCarter [171] report that streptomycin hydrochloride administered subcutaneously had a distinct suppressive effect on experimental pulmonary tuberculosis in white mice. In the second and most successful experiment, administration of streptomycin in a dosage of 3,000 units daily was started on the day that mice were infected by intravenous inoculation of a human strain of tubercle bacillus. The treatment was continued for twenty-eight days, at which time 87 per cent of the treated animals were living, whereas 2 per cent of the controls were still alive. The lungs of the control animals all exhibited gross lesions estimated to occupy 39 per cent of the pulmonary substance. In the treated mice no gross lesions were visible, but all exhibited microscopic lesions containing tubercle bacilli.

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168. Youmans, G. P.: Effect of Streptomycin in Vitro on M. Tuberculosis var. Hominis, Quart. Bull., Northwestern Univ. M. School **19**:207-209, 1945.

169. Feldman, W. H., and Hinshaw, H. C.: Effects of Streptomycin on Experimental Tuberculosis in Guinea Pigs: Preliminary Report, Proc. Staff Meet., Mayo Clin. **19**:593-599 (Dec. 27) 1944.

170. Feldman, W. H.; Hinshaw, H. C., and Mann, F. C.: Streptomycin in Experimental Tuberculosis, Am. Rev. Tuberc. **52**:269-293 (Oct.) 1945.

171. Youmans, G. P., and McCarter, J. C.: A Preliminary Note on the Effect of Streptomycin on Experimental Tuberculosis of White Mice, Quart. Bull., Northwestern Univ. M. School **19**:210, 1945; Streptomycin in Experimental Tuberculosis: Its Effect on Tuberculous Infections in Mice Produced by M. Tuberculosis var. Hominis, Am. Rev. Tuberc. **52**:432-439 (Nov.) 1945.

Hinshaw and Feldman,[172] in a preliminary report based on nine months of collaborative experience with others in the use of streptomycin in 34 tuberculous patients, gained the impression that streptomycin exerted a limited suppressive effect, especially on some of the more unusual types of pulmonary and extrapulmonary tuberculosis. The authors regard 800,000 units per twenty-four hours as the minimum therapeutic dose. Patients were usually given 1,000,000 to 2,000,000 S units per day.

Gerstl, Tennant and Pelzman [173] report on a study in which mycolic acids isolated by Anderson and associates as long chain hydroxy fatty acids from waxes of human, bovine and avian tubercle bacillus and leprosy bacillus were injected into experimental animals. The lesions in general are similar to those described, for the waxes and the particles are acid fast, but there is initial and decided necrosis. This reaction in rabbits persists with low-melting human, and particularly with bovine, mycolic acid; however, the high-melting human mycolic acid and leprosonic acid are only slowly fragmented into small particles and cause initial but nonpersistent necrosis, and the subsequent lesions are small, consisting largely of giant cells that contain vacuoles and are surrounded by a minimal proliferative reaction. The mycolic acids as constituents of the tubercle bacilli may be assumed to contribute to the persistence of lesions induced by this micro-organism, but there is no evidence that they are related to the elective pathogenicity of different types of tubercle bacilli.

Because of the important part calicum plays in body physiology and because of the discordant views, Rai and Kehar [174] undertook a study to determine the absorption of calcium in normal and tuberculous persons under different dietary conditions and also with the addition of ascorbic acid to the diet. The authors draw these conclusions: 1. The serum calcium content of healthy persons with a normal level or of patients with pulmonary tuberculosis with a subnormal level could not be raised, in spite of the feeding of calcium salts for six weeks, if the diet did not contain appreciable quantities of vitamin C. 2. If the diet either contained vitamin C-rich components or was supplemented with ascorbic acid, the serum calcium level increased within a reasonable period. 3. The level of serum calcium rises to the optimum level of normal range.

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172. Hinshaw, H. C., and Feldman, W. H.: Streptomycin in Treatment of Clinical Tuberculosis: A Preliminary Report, Proc. Staff Meet., Mayo Clin. **20**:313-318 (Sept. 5) 1945.

173. Gerstl, B.; Tennant, R., and Pelzman, O.: Cellular Reactions to Mycolic Acids, Am. J. Path. **21**:1007-1019 (Sept.) 1945.

174. Rai, B. B., and Kehar, N. D.: Studies on Absorption of Calcium by Normal and Tuberculous Subjects Under Different Dietary Conditions, Antiseptic **42**:243-249 (May) 1945.

In 1941 there were fifteen thousand, five hundred and seventy-eight beds in special children's sanatoriums in the Soviet Union for the treatment of tuberculosis of the bone. Krasnobiev [175] states that many other patients were treated at home, under careful medical supervision, and with equally good results. Treatment is essentially conservative—fresh air, sunshine, rest, orthopedic surgery when necessary and diet. Schoolwork, music and art are taught the children during their treatment.

The average number of days of stay in a sanatorium for the period from 1918 to 1940 was as follows: spondylitis, 1058; coxitis, 1014, and tuberculosis of the knee joint, 725. The percentages of patients discharged with quiescent disease were as follows: spondylitis, 77.5; coxitis, 85.1, and tuberculosis of the knee joint, 85.0. No mention is made of the amount of operation or of the type of the procedures performed. No follow-up is given.

VIII. INFECTIONS OF THE BONES AND JOINTS

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ACCORDING to Elkin and Kelly,[176] a near disaster from hemorrhage of the posterior tibial vessels in the course of the excision of an arteriovenous aneurysm prompted the approach to these vessels by the removal of the upper portion of the fibula, including the resection of the head of that bone where necessary. The rich collateral anastomosis which develops as the result of an arteriovenous communication, together with dilatation of the vessels, including those which perforate the interosseous membrane, demands direct visualization of these vessels and their careful ligation and division. Otherwise the retraction of vascular channels through the interosseous membrane may result in serious or even uncontrollable hemorrhage and necessitate a second incision along the front of the leg or the removal of the fibula in the presence of hemorrhage and at an inopportune time during the course of the operation.

The exposure of the fibula and the method of its removal have been described by Henry, and it was a modification of his procedure which Elkin and Kelly followed, with successful results in 15 instances. The fibula is removed subperiosteally, thus insuring continued stability of the knee joint. Moreover, the peroneal nerve, which may be concomitantly injured along with the vessels, is at the same time exposed and may be explored or repaired without further operative incision.

175. Krasnobiev, T. P.: Joint Tuberculosis in the Soviet Union, Am. Rev. Soviet Med. **2**:270 (Feb.) 1945.

176. Elkin, D. C., and Kelly, R. P.: Arteriovenous Aneurysm, Ann. Surg. **122**: 529-545 (Oct.) 1945.

Resection of the fibula for exposure of these vessels is necessary only in their course in the upper portion of the leg. In the lower third they are more easily reached by direct approach along the posterior surface of the tibia on the medial side of the leg.

Careful exposure of the tibial and peroneal vessels in the upper part of their course is necessary in the operative treatment of arteriovenous fistulas in this region. This is facilitated by subperiosteal resection of the fibula, including the head of the bone if necessary. The resected portion of bone is not replaced. There has been no instability of the knee joint following this operation. Fifteen consecutive cases in which this procedure was carried out are presented in abstract.

[ED. NOTE.—The illustrations are beautiful and profuse. This valuable presentation is the work of two authorities. Rudolph Matas made the statement that the medical personnel at the Ashford General Hospital saw more peripheral vascular surgical lesions in three months than he had seen in fifty years.]

Kelly, Rosati and Murray [177] report that during the past two years an extensive experience with the application of skin grafting to the treatment of osteomyelitis resulting from war wounds has been accumulated at Ashford General Hospital. This procedure is neither new nor original. Lord reported Thiersch grafting of osteomyelitic cavities in 1902. Reid in 1922 published a concise report covering most of the important aspects of the subject. Armstrong and Jarman as well as Quick reported the use, the latter over a period of twenty years, of a technic similar to that employed by Kelly and associates. Neuber, in 1895, and Lord and Beekman, somewhat later, have written of the applicability of pedicle skin grafting to the arrest of this condition.

There have been occasional reports of the successful application of skin grafting in the treatment of osteomyelitis of hematogenous and of traumatic origin for many years. This procedure has failed to gain wide acceptance. It has been successfully carried out by the technic as described for over two years at an Army general hospital. This is a safe form of surgical treatment. Beneficial results can be anticipated in the majority of cases, with loss of little more than skin in the failures. The use of skin grafting in traumatic osteomyelitis has failed to receive the general adoption its effectiveness warrants.

[ED. NOTE.—This is a welcome presentation of a method advocated many years ago by J. B. Murphy, of Chicago, and J. P. Lord, of Omaha, Neb. I had personal experience with J. B. Murphy in 1911 when he was employing this method. It has been improved chiefly by the addition of chemotherapy.]

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177. Kelly, R. P.; Rosati, L. M., and Murray, R. A.: I. Traumatic Osteomyelitis: The Use of Skin Grafts, Ann. Surg. **122**:1-11 (July) 1945.

Bagley [178] chose the knee joint for administration of penicillin because of its size, its accessibility and the expectation of delayed dialization through a synovial membrane, giving prolonged administration of this drug which is excreted so rapidly by all usual methods of administration. He has used this method over eighty times, in a few instances using both knees, one in the morning and the other at night, for several days; 80 per cent of the doses were 100,000 units in 10 cc. of sterile water. Some patients had a little discomfort for five or ten minutes immediately following injection. With the use of 2 cc. of 1 per cent procaine hydrochloride in the joint several minutes preceding the injection of penicillin patients had no discomfort.

The method Bagley uses is to dissolve the penicillin in 10 cc. of sterile water, using a no. 16 needle to perforate the stopper and aspirate the solution. With a 23 caliber 1½ inch (3.7 cm.) needle 2 cc. of procaine hydrochloride is injected into the knee joint hugging the patella near the insertion of the tendon. After the contents of the knee are massaged for several minutes with the needle in place, the 10 cc. of penicillin is injected through this needle, and an ice bag is placed on the knee for the next eight or ten hours. The sodium preparation made by four different companies was used. The lighter-colored brands seemed a trifle less irritating.

Since writing this article, Bagley has had apportioned to one hospital some deep orange-colored, 100,000 unit penicillin of considerable bulk. This penicillin given intramuscularly is painful, and in the knee joint it is extremely painful and causes swelling. This reaction is evidently due to foreign matter in the preparation and should call for better controlled laboratory methods in its manufacture. Its presence also may harm parenchymatous organs which have been immune to injury from the purer penicillin, which is nearly white. The light lemon-colored penicillin has given little discomfort, and it would seem that the lack of irritation is an index of purity.

Bagley uses isotonic solution of sodium chloride to dissolve the penicillin, every cubic centimeter representing 10,000 units. The high potency, less distensible volume and relatively painless administration with use of an ordinary hypodermic needle, usually without preliminary anesthesia induced with procaine hydrochloride, makes this a practical method of administration, especially outside of the hospital. The knee is slightly flexed and relaxed. The fingers of the left hand press out from the inner edge of the patella. The center of the lower edge of the shelving projection of the patella is the mark for entrance into the synovial bursa underneath. A 1 inch (2.5 cm.) hypodermic needle will pass through 99 per cent of the synovial sacks at this point. Infections of the extremities, which formerly were treated with hot compresses and

178. Bagley, W. R.: Administration of Penicillin by the Knee Joint Method, Minnesota Med. **28**:205-206 (March) 1945.

sulfonamide derivatives are now treated with penicillin, 10,000 units per cubic centimeter, 10,000 to 100,000 units being injected distal to and in line with the lymphatic vessels and return circulation. The infected area is subjected to a concentrated shower of penicillin such as no general distribution over the body can give, and many times if used before actual necrosis of tissue it will prevent abscess formation. The light lemon yellow solution, penicillin in isotonic solution of sodium chloride, 10,000 units per cubic centimeter, causes little irritation of tissue. Bagley has used 20,000 units in a finger, 40,000 units in the forearm of a 6 year old child and 100,000 units in a leg in which the thigh had been lacerated by the bite of a boar hog. Tetanus serum and injections of penicillin into the knee were also used in this case. The determination of the type of infection is not practical in many of such cases, but Bagley is sure that the motto "use penicillin first" is safe and many times almost miraculous in the curative results, also using large enough doses. With the purer, light-colored penicillin preparation which a number of reliable pharmaceutical houses are putting out, the reactions in the tissue are nothing to extremely mild, and it is believed that it is largely due to volume and too rapid infiltration that there is any discomfort. The concentration of 10,000 units per cubic centimeter of isotonic solution of sodium chloride permits the use of large and effective dosage.

According to Flynn,[179] the view that early administration of adequate doses of the sulfonamide compounds is not in itself sufficient to limit the severity of osseous infection finds support in the experience of roentgenologists. In a series of studies, by means of roentgenologic examination of patients under treatment with sulfonamide drugs, it can be shown that the clinical picture is often not very impressive. A condition far different from that which he was led to expect from the absence of clinical signs will confront the observer. The active progression of the disease, as revealed by roentgenograms, will suggest immediate surgical intervention. Since roentgenologic examination will reveal the exact location and extent of the infection, serial roentgenograms would aid greatly in the treatment of patients with suspected osteomyelitis.

The treatment of acute osteomyelitic infections demands adequate operation in combination with use of the sulfonamide drugs.

Good surgical treatment means that every bit of necrotic and infected bone has been removed and that the longitudinal edges of the remaining bone are flat enough to allow soft tissue to fall over and cover the bone. With a correct technic, the end result is good regardless of the type

179. Flynn, J. M.: Symposium: Changes Which Have Resulted from the Use of Sulfa Drug Therapy in Management of Osteomyelitis, New York State J. Med. **45**:493-494 (March 1) 1945.

of chemotherapy which is used postoperatively. The preoperative use of such therapy has its value.

Kross [180] points out that there has recently appeared in the literature an article (*Ann. Surg.* **119:** 178, 1944) in which refrigeration anesthesia in surgery is discussed from both the experimental and the clinical point of view. The character of this work on the whole is of such high grade that if all the author's conclusions are accepted without question or challenge it will cause an unnecessary delay in the application of a therapeutic measure that has proved itself beyond any doubt to be of great value in surgical treatment of the extremities. In the body of the paper the statement is made that "cooling per se does not seem to have a beneficial effect on an inflammatory process. While the infected part is cooled there is an inhibition not only of bacterial growth and toxin production but also of the normal tissue response."

The report of a case is published because it is, as far as Kross knows, one in which refrigeration or low temperature treatment was employed for the longest time on record, with the successful preservation of a limb that in ordinary circumstances would have been amputated. It also shows the necessity of continuing with the treatment until the infection is fully and completely overcome.

Dickson [181] states that persistent areas of destruction of bone constitute potential sources of trouble. Wilson and McKeever reported 3 patients with acute hematogenous osteomyelitis treated by administration of the sulfonamide compounds without drainage, with subsidence of acute symptoms, in which several months later drainage was established because of persistent local induration. Thick, soft, hyperplastic bone was encountered and granulation tissue was found in the medullary canal when drainage was established. Smears and cultures revealed staphylococci. These findings clearly indicate that such quiescent foci are not really sterile but that they probably harbor dormant bacteria capable of activity.

Treating an abscess of the bone with the sulfonamide drugs and without drainage may be similar to putting out the fire, but letting the ashes remain; only too frequently the ashes have embers which are likely to be fanned into activity by such breezes as lowered resistance or local trauma to the quiescent area. Dickson's observations have convinced him that sooner or later a large percentage of these quiescent foci do become active. Whether penicillin proves to be an agent which, more powerful than the sulfonamide drugs, will completely sterilize such

180. Kross, I.: Low Temperature Therapy for Preservation of Limbs, J. A. M. A. **128:**19-20 (May 5) 1945.

181. Dickson, F. D.: Clinical Diagnosis, Prognosis, and Treatment of Acute Hematogenous Osteomyelitis, J. A. M. A. **127:**212-217 (Jan. 27) 1945.

areas of infection only time will tell. Until then the preponderance of evidence is in favor of early drainage of the osseous focus in acute hematogenous osteomyelitis except in the fulminating type with septicemia and pyemia, when the drainage of a single focus, where there are probably others present, cannot be expected to have any helpful effect but will probably do harm.

[Ed. Note.—The author is a pioneer in the field. The general practitioner still needs expert advice and help.]

Higley and Rude [182] have had the opportunity of using penicillin in approximately 25 cases of infection of the bone, both acute and chronic, with varying results. They report cases demonstrating the typical changes occurring in infections of the bone susceptible to treatment with penicillin. In general, the period of active infection has been shortened and the clinical results have been gratifying. The summaries of cases and illustration demonstrate what these authors believe to be the typical changes.

The summaries of cases presented represent several types of osseous infection in which Higley and Rude feel that definite improvement followed the use of penicillin. It is their opinion that, in general, the treatment of osseous infections with penicillin has been satisfactory. The response varies in individual cases. In most instances the period of active infection was considerably decreased. In the patients who had a favorable response to penicillin, clinical improvement preceded any roentgenographic evidence of healing. The roentgenographic evidence seen in their cases is as follows: (1) apparent arrest of the spread of the infection, with little or no sequestration of bone and little or no involucrum; (2) positive evidence of healing, in the form of a reactive recalcification of the affected areas, the recalcification appearing throughout the cortex of the bone and approaching the normal architecture of the bone much more closely than does the ordinary involucrum in osteomyelitis (the area of recalcification was of slightly greater density than normal bone), and less resultant end sclerosis than is commonly seen in extensive osteomyelitis which has run the normal evolutionary course; (3) since the progress of the infection in these cases was apparently arrested and the reparative process begun before extensive spread, sequestration and involucrum had appeared.

[Ed. Note.—It is difficult for many pediatricians and radiologists and some orthopedic surgeons to determine the difference between progress and progression of the disease. It requires experience and a careful evaluation of general, constitutional and local factors.]

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182. Higley, G. B., and Rude, J. C.: Roentgenographic Changes in Bone Infections Treated with Penicillin, Radiology **44**:115-124 (Feb.) 1945.

Burns, Moss and Brueck [183] have observed that mycetoma pedis, or madura foot, is a chronic mycotic infection characterized by enlargement and deformity of the foot with the production of multiple abscesses and sinuses which extend deep into the involved tissues. Pus, containing colonies of micro-organisms in the form of granules, is discharged through the sinus tracts to the surface of the skin.

At the present time, it is customary to classify these infections of the foot under the term mycetoma, which by definition has been taken to include all chronic infections which are caused by fungus-like organisms and are associated with the production of granules which appear in the tissues and are discharged in the pus. Because of the distinctive characters of the mycetomas involving the foot, these have sometimes been designated as mycetoma pedis, and in the authors' opinion this designation, which separates the disease from mycetomas located in other parts of the body, is fully justified. Further classification of mycetoma pedis should be followed along two lines: (1) mycetoma pedis due to actinomyces and (2) mycetoma pedis due to true fungi. The latter disease has been heretofore classified as maduromycosis.

Three cases of mycetoma pedis occurring in natives of Louisiana are reported. The findings in 38 cases of mycetoma pedis occurring in the United States and Canada are summarized.

[ED. NOTE.—This rare condition is characteristically described. The surgeon always has time to look up the subject if he is alert and keeps it in mind.]

Cooke [184] claims that many of the methods for penicillin assay have been devised and used primarily for testing solutions during the production of penicillin and are not easily applicable to the determination of titers of body fluids in patients under treatment. These have been reviewed by Foster and Woodruff, the classic test of Florey being in commonest use. Of the studies made on body fluids, the method described by Rammelkamp involving the use of serial broth dilutions and a strain of hemolytic streptococcus was used by Rammelkamp and Keefer. Rosenberg and Sylvester have used Foster's method of serial broth dilution with Staphylococcus aureus and turbidimetric measurements, while Romansky and Rittman have used a method described by Rake and Jones based on the property of the inhibition of hemolysin production of streptococci by penicillin. The procedure described by Cooke is believed to be simpler than some of the other methods men-

183. Burns, E. L.; Moss, E. S., and Brueck, J. W.: Mycetoma Pedis in United States and Canada: Report of Three Cases Originating in Louisiana, Am. J. Clin. Path. **15**:35-49 (Feb.) 1945.

184. Cooke, J. V.: Simple Clinical Method for Assay of Penicillin in Body Fluids and for Testing of Penicillin Sensitivity of Bacteria, J. A. M. A. **127**: 445-449 (Feb. 24) 1945.

tioned, is easily applied to the study of body fluids for determination of the titer of penicillin and utilizes only materials and methods familiar to all bacteriologic technicians. In addition it can be readily used for determination of the sensitivity to penicillin of various strains of Staph. aureus or other organisms. A large number of titrations on blood serum and other body fluids, including spinal fluid, pleural and ascitic fluids and subcutaneous edema fluid, have been performed, and the results have appeared to be consistent. They will be summarized and discussed in a separate report.

The method consists essentially in determination of the lowest concentration of penicillin which will produce complete inhibition of growth of a standard strain of Staph. aureus on a plain agar Petri plate.

Tests on various strains of Staph. aureus and meningococci by a method for assay of penicillin in body fluids have shown a considerable variation in sensitivity to penicillin.

[ED. NOTE.—This is a matter for the laboratory expert. The orthopedic surgeon should keep in mind the fact that it is possible to obtain this information, which in certain situations may be valuable.]

Hamilton[185] notes that the discovery in 1929, by Fleming, of an antibacterial substance obtained from a mold, Penicillium notatum, has led to the development of one of the most marvelous therapeutic agents in the treatment of disease in human beings in the history of medicine. Its profound therapeutic value in the treatment of acute osteomyelitis when due to susceptible micro-organisms fully justifies the presentation of this paper. Hamilton draws the following conclusions:

Penicillin is a marvelous and powerful antibacterial agent. Its discovery by Alexander Fleming was more or less by accident. It acts as both a bacteriostatic and a bactericidal agent under certain conditions. Its high antibacterial power is coupled with low toxicity to tissue cells. It is reasonable to presume that since penicillin has become plentiful and the general medical profession has been properly alerted chronic osteomyelitis will be almost a disease of the past.

[ED. NOTE.—Every reader of this paper or abstract who reflects on his days in the bacteriology laboratory can say (with no pride), "I saw many times what Fleming saw, but I was too stupid to know at what I was looking."]

According to Rooney,[186] in severe dehydration in infants it is at times difficult to restore the fluid balance because of mechanical difficulties of intravenous injections. The blood vessels are small and collapse easily; cutting down on the vessels requires skill and is time

185. Hamilton, J. F.: Penicillin in Treatment of Acute Osteomyelitis, Memphis M. J. **20**:146-148 (Oct.) 1945.

186. Rooney, E. F.: Bone Marrow Infusion with Two Cases of Localized Osteomyelitis, Arch. Pediat. **61**:611-616 (Dec.) 1944.

consuming. When Tocantins and O'Neill reported the rapidity with which blood and other substances were absorbed from the marrow cavity and later reported successful infusions into the bones of infants, Rooney decided to try their method.

The site selected is the proximal end of the tibia or the distal end of the femur. Special needles are used, usually the internal needle gage 18 being selected for the smaller infants. The extremity is attached to a posterior splint, and the skin over the site selected is surgically prepared. The needle is forced through the skin to the periosteum; then with increasing force and rotation the needle penetrates into the medullary canal. This is recognized by the definite feeling of decreased resistance and of the needle becoming firmly fixed in the bone. Suction is then applied to the needle with a 5 cc. syringe filled with isotonic solution of sodium chloride and bone marrow withdrawn into the syringe. When the needle is definitely in the medullary canal, it is flushed with isotonic solution of sodium chloride, and an ordinary infusion set containing the fluid is attached. If the rate of flow of blood is too slow, it may be diluted with isotonic solution of sodium chloride or by injecting the blood with a 10 cc. syringe directly through the needle. Success was so uniform that the succeeding one hundred and fifty infusions were given as a hospital procedure.

A summary is given of the use of this method in the first one hundred infusions. All patients were infants from 3 days to 9 months of age, and their weights ranged from 4 to 14 pounds (1,814 to 6,350 Gm.), the average weight being 6½ pounds (2,947 Gm.).

Intramedullary infusion in infants is a relatively simple and successful procedure. Careful asepsis must be maintained at all times and the needle immediately removed when signs of infiltration of the periosteum or soft tissue are present.

[Ed. Note.—In certain situations of almost despair this is a life saver.]

Ryan and his associates [187] anesthetized mice weighing between 20 and 30 Gm. by a subcutaneous injection of pentobarbital sodium (0.005 cc. of a solution, containing 25.4 mg. per cubic centimeter of distilled water, per gram of body weight). The extensor muscles of the thigh were exposed by an incision about 5 mm. long, and the appropriate amount of a whole culture of clostridia was injected into the vastus lateralis. The belly of the extensor muscles was then crushed with a fine hemostat for about 3 mm. of its length. After one-half hour about 5 mg. of the compound to be tested was spread into the wound, and the incision was closed with a cotton suture. Independent tests

187. Ryan, F. J.; Ballentine, R.; Schneider, L. K., and Tuck, G. M.: Certain Sulfonamide Drugs and Certain Derivatives of Ascorbic Acid in Experimental Gas Gangrene in Wounded Mice, Surgery **17**:47-53 (Jan.) 1945.

showed that the compounds used were not lethal in dosages several times those employed in therapy.

The operation itself was not lethal, since all of 14 mice survived when infection was not attempted. In addition, no deaths occurred in 27 cases in which infection was attempted with 0.5 cc. of old (twenty-four to thirty-hour) cultures of Clostridium perfringens.

It was possible to kill mice by simply dropping the culture into the incision before the muscles were crushed (that is, without injecting the bacteria into the muscle). However, it was thought that the assay would be more rigorous by admitting bacteria into the muscle sheaths of connective tissue. Care was taken to make the operation and infection as constant as possible from experiment to experiment. In two strains of mice the local application of sulfadiazine saved about 60 per cent of the animals infected with Cl. perfringens, a significant difference from the controls. Sulfathiazole was also effective against Cl. perfringens in one strain of mice but not in others. In one strain of mice ascorbic acid saved about 40 per cent of the animals infected with Cl. perfringens, a significant difference from the controls. However, it was ineffective against gas gangrene in other strains. Ascorbic acid, sulfadiazine and sulfathiazole were ineffective against infections caused by Clostridium novyi, Clostridium histolyticum, Clostridium sordellii and Clostridium septicum.

Warmer and Amluxen [188] found that tests in vitro to determine the sensitivity to penicillin of organisms cultured from patients with infections were useful in the selection of patients suitable for treatment with penicillin and in the regulation of the course of treatment. The concentration of penicillin in the blood of patients receiving injections intramuscularly every three hours with 25,000 units of this substance seldom rises above 0.1 unit per cubic centimeter. Immediately after the administration, intravenously, of 10,000 units of penicillin, the level reaches little more than 1.0 unit per cubic centimeter. Tests in vitro with concentrations of penicillin in these ranges usually give evidence that the organisms being tested are either sensitive or resistant to the levels of penicillin in the blood of patients being treated.

In experiments in which mice were used, a strain of hemolytic Staph. aureus that was resistant to penicillin in vitro proved also to be resistant to comparable concentrations of penicillin in vivo.

Kemp [189] observes that in the present war cases of gas gangrene were fewer than they were in 1914 to 1918, but the disease still remains one

188. Warmer, H., and Amluxen, J.: Comparison of in Vitro and in Vivo Penicillin Resistance of Strain of Hemolytic Staphylococcus Aureus, J. Lab. & Clin. Med. **30**:419-421 (May) 1945.

189. Kemp, F. H.: X-Rays in Diagnosis and Localisation of Gas Gangrene, Lancet **1**:332-336 (March 17) 1945.

of the principal causes of death from wounds. According to MacLennan and Macfarlane (1944) the case fatality rate has been about 50 per cent. Gas gangrene may follow the most trivial wound. In war time, anaerobic infections of wounds occur frequently, but in nearly all cases, with efficient treatment, the infection is overcome. If attention to the wound is delayed, the organisms may multiply in blood clot or dead tissue without serious ill effects, but once they start to invade healthy tissues the disease may run so swift a course that the patient is dead within a few hours. Every one admits that successful treatment of gas gangrene depends on its early recognition. Even an experienced surgeon finds this difficult, and he must not amputate a limb which can be saved or procrastimate until it is too late to save the patient's life.

During the last war a number of observers noted that it was possible to detect gas in the tissues by means of roentgen rays. In England Dr. J. F. Brailsford is the foremost authority. He has stated the belief that it is possible to give an immediate answer to the question "Is there any evidence of gas gangrene?" long before the infection has produced serious clinical signs.

Kemp has made it a rule to reexamine every patient who complains of increasing local pain or discomfort in the tissues around his wound. As a rule, examinations every three hours are sufficient, but in some instances in which the clinical course changes rapidly it may be necessary to examine the patient every hour. If a limb is encased in plaster, a roentgenographic examination is useless and the plaster should be removed.

I do not believe that there are any characteristic clinical signs of early gas gangrene. Many wounded persons show slight signs of general reaction, and a few may be profoundly ill from other causes. The local signs are difficult to assess. I am in complete agreement with authorities who maintain that crepitation is not a reliable guide. As a rule crepitus cannot be felt unless there is gas in the subcutaneous tissues, and Kemp doubts that gas crepitations can be felt in the muscles unless the muscles have already disintegrated. There is no reason why any patient should not be roentgenographically examined. The patient will suffer no harm, for he need not be moved or exposed. If the roentgenographic findings are suggestive, the surgeon need do no more than keep the patient under observation, but if the local condition does not improve or grows worse the examination should be repeated, for serial roentgenographic examinations offer incontestable evidence of formation of gas.

If spreading gas gangrene is established, the radiologist should secure a complete examination of the entire limb or part affected. Some years ago Kemp saw a reputable surgeon amputate through muscles which from the roentgenographic appearances were widely

infiltrated with gas, without recognizing that the infection was present. He was under the impression that he had eradicated the infection, but it was clear that he had not; shortly afterward the patient died. It is a fact that at operation it may be difficult to recognize that the muscles are infiltrated with gas. They may look normal and there may be no ordinary crepitation, though it may be possible to recognize a difference in texture when the muscles are cut with a knife.

A surgeon need not necessarily remove all the infected tissues; it is sufficient to remove the infected muscles and use chemotherapeutic measures to overcome any infection which has been left behind in the loose cellular tissues.

An account is given of the clinical and roentgenologic features of 331 battle casualties admitted to a hospital in Great Britain. The report deals in detail with the roentgenographic appearances of air in the tissues, local formation of gas and gas gangrene and gives a detailed account of the clinical application of these findings.

O'Reilly [190] has tried to point out that syphilis of the bones and joints may simulate many other conditions and that it should always be kept in mind. Lesions of syphilis of the bones and joints have probably been lessened by the earlier and more thorough treatment of the disease, but they are still present. In all cases if syphilis is present it should be known. A routine Wassermann test should be made in all cases, and a careful history should be taken. A surgeon should always try to elicit the presence of syphilis in the history. Not only may syphilis cause lesions of the bones and joints, but it may complicate other lesions. Its treatment should be early and prompt.

Potassium iodide and mercury seem to act more rapidly than the arsenicals, but care must be used to see that the patient is given the proper constitutional treatment. For this reason orthopedists and syphilologists should closely cooperate.

Altemeier and Reinecke [191] point out that penicillin has revolutionized the management of acute hematogenous osteomyelitis. The spectacular control of bacteremia, the bony infection and the metastatic visceral infectious complications has produced a radical reduction in morbidity as well as mortality rates. This control of the infection has been so effective that emergency surgical decompression of the area of involved bone has not become necessary except in fulminating conditions. Instead, the required operation has usually been limited to incisions and drainage of abscesses developing in soft tissues and to the

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190. O'Reilly, A.: Syphilis as It Affects Orthopedic Surgery, Urol. & Cutan. Rev. **49**:243-245 (April) 1945.

191. Altemeier, W. A., and Reinecke, H. G.: Roentgenographic Interpretation of Acute Hematogenous Osteomyelitis Treated with Penicillin, Am. J. Roentgenol. **54**:437-438 (Nov.) 1945.

removal of selected large and unabsorbed sequestrums. The disfiguring sequelae, such as deformity, limp, draining sinuses or ankylosis of adjacent joints, have been largely eliminated. Likewise, a careful study of the patients treated with penicillin has forced these authors to modify their earlier conceptions and interpretations of the roentgenographic changes occurring in acute hematogenous osteomyelitis.

In twenty-seven months they observed the results of tretament with penicillin in 52 cases of acute hematogenous osteomyelitis. The group included 44 cases of acute hematogenous osteomyelitis of the major long bones, in some of which there was also involvement of the flat bones of the pelvis. In addition, there were 4 cases with involvement of the pelvic bones only. The responsible etiologic agent was determined in every instance but 4 and was found to be hemolytic Staph. aureus in 42 cases, nonhemolytic Staphylococcus albus in 3, hemolytic streptococcus in 1 and Pneumococcus type III in 1.

Although the roentgenogram is of little or no value in making an early diagnosis of acute hematogenous osteomyelitis, it is of definite value in the recognition of the process after ten to fifteen days beyond the onset. A succession of changes occurring in bone has been described in the patients treated adequately with penicillin and have been interpreted as a measure of the process of spontaneous repair and not as an indication of further extension of the osteomyelitic process, as has been generally assumed. The spontaneous removal of necrosed bone has been followed by recalcification and healing of the involved areas.

Kirby [192] states that an enzyme-like substance capable of destroying penicillin was produced from Escherichia coli and certain other saprophytic and commensal bacteria in 1940, but attempts to extract a penicillin inactivator from sensitive or resistant staphylococci were unsuccessful. More recently, acetone-ether extracts of paracolon bacilli, which were more effective inhibitors of penicillin than were extracts of Esch. coli, were prepared.

In this country, it was found that clarase, a diastatic enzyme preparation, readily destroyed penicillin, and this substance is now used widely for sterility tests during production of penicillin. Apparently, the ability to inactivate penicillin is possessed by only certain lots of clarase, and this action is attributed in a later publication to the presence of bacterial products, especially of Bacillus subtilis and related gram-positive organisms.

A penicillin-destroying staphylococcus has been found contaminating a culture of Aspergillus flavus, and independently in Kirby's laboratory,

192. Kirby, W. M. M.: Properties of Penicillin Inactivator Extracted from Penicillin-Resistant Staphylococci, J. Clin. Investigation **24**:170-174 (March) 1945.

a highly potent inactivator of penicillin has been extracted from penicillin-resistant staphylococci obtained from clinical sources. Kirby presents details of the extraction and properties of this substance. This highly potent inactivator of penicillin was extracted from seven strains of Staph. aureus which were naturally resistant to penicillin; seven sensitive strains did not produce a penicillin-destroying substance. The resistant bacteria were not lysed but were by no means completely resistant to the bacteriostatic action of penicillin. This differentiation between resistance to lysis and resistance to bacteriostasis is discussed elsewhere.

It is of fundamental importance to determine whether the several inactivators of penicillin so far described are identical or whether penicillin can be destroyed by substances whose chemical structures are unrelated. Properties of the known inactivators of penicillin are summarized. Presumably they are all products of bacterial metabolism, but whether they are produced by all penicillin-resistant organisms has not yet been definitely determined. The differences in properties are relatively superficial and possibly largely due to differences in technical methods. Further chemical studies are necessary for final clarification.

Myers and Lenahan [193] claim that because of the chronicity of osteomyelitis recovery in their case may have been apparent only, and due instead to a spontaneous remission. However, this seems unlikely in that there was no fever or pain or other evidence of the disease in more than seven months; the patient gained weight and otherwise improved steadily, and roentgenograms indicated that healing of the bone was taking place.

The question arises as to whether the penicillin was contributory to the recovery in view of the demonstrated complete fastness of the organism recovered from the draining sinus after the second course of penicillin. That it was seemed probable because the patient received no specific treatment other than penicillin, and spontaneous recoveries of untreated patients with chronic osteomyelitis are uncommon.

Recovery followed the intramuscular administration of two courses of 1,000,000 units (0.6 Gm.) and 2,500,000 units (1.5 Gm.) of penicillin five months apart in a case of osteomyelitis of a femur and ilium, of thirty months' duration, together with chronic otitis media in an 11 year old boy. Repeated prolonged heavy courses of sulfathiazole administered previously had been ineffective. Cultures of staphylococci recovered from a draining sinus immediately following the second course of penicillin were fast to penicillin in vitro. Recovery in spite

193. Myers, W. G., and Lenahan, F.: A Case of Osteomyelitis Treated with Penicillin with Unusual Bacteriologic Findings, Ohio State M. J. **41**:422-425 (May) 1945.

of the development of this fastness to the drug is attributed to an associated concomitant loss either of virulence of the organism or of insusceptibility to the antibacterial action of blood or both. The fastness of the organism to penicillin largely disappeared after several months of storage at 3 to 5 C.

During the first course of penicillin, chickenpox appeared on the sixth hospital day in spite of the drug. This is another instance of the ineffectiveness of penicillin in many virus infections.

An average of 48 per cent of the daily dose appeared in the urine; the range was 22 to 84 per cent. The concentration varied between 9 and 38 units per cubic centimeter of urine, depending somewhat on the volume excreted. Penicillin had ceased to appear in the urine within twenty-four hours after the last intramuscular dose.

As Professor Fleming has remarked, it would be a most unusual accident if the first successful antibiotic would prove to be the best one. Myers [194] notes that at present there is a widespread search for other antibiotics which will be effective against pathogenic organisms that are insusceptible to penicillin, that will be more easily produced, more stable, that can be taken by mouth or that can be readily synthesized. Among the many which have been described are gramicidin, tyrothricin, streptothricin, streptomycin, actinomycin, clavacin, gliotoxin and penatin. However, most of them do not combine the lack of toxicity with the effectiveness possessed by penicillin. Of particular interest is streptothricin, since it is reported to be effective against the organisms that are responsible for typhoid fever and bacillary dysentery, an important group of gram-negative pathogens against which penicillin is entirely ineffective.

Wood [195] calls attention to the fact that in North America maduromycosis (madura foot, or mycetoma) has been a rare and little known disease, in contrast to India and the Dutch East Indies, where it is prevalent and well recognized. Because larger numbers of men from the United States were exposed to infection by the fungi which give rise to maduromycosis, he reports a case recently seen in a United States naval hospital in which the condition, of the melanoid variety, involved the left ankle of a Filipino 40 years of age. The mycotic lesion had been present for at least seven months. Early in its course the overlying skin had ulcerated for a short time, but it subsequently healed. On surgical dissection the lesion was found to be circumscribed and subject to complete excision. No distant lesions were evident. Etiology is briefly discussed.

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194. Myers, W. G.: Penicillin: A Potent New Chemotherapeutic Agent, Ohio J. Sc. **44**:277 (Nov.) 1944.

195. Wood, D. A.: Maduromycosis of the Ankle: Report of a Case, California & West. Med. **62**:119-121 (March) 1945.

Symmers[196] reports that up to 1945 twenty-two species of fungi belonging to ten genera and four families had been implicated in the production of the various types of maduromycosis. In spite of this multiplicity of causes, the different types clinically may resemble one another closely, and in some instances they may also resemble actinomycosis, especially if the latter disease is confined to a lower extremity, as is maduromycosis in many cases. Clinically, cases of maduromycosis may be divided into three groups. In all of them the lesions are limited to the part which was originally infected, as the foot, hand, knee, neck or face.

Phialophora jeanselmei when injected subcutaneously into rabbits produces solitary nonulcerative nodules which histologically are specific and are closely comparable to the nodules in that form of maduromycosis in human beings which is caused by the same fungus.

Symmers and Sporer[197] also discuss maduromycosis. Maduromycosis, or mycetoma, madurosis or, as it is perhaps most widely known, madura foot, is a fungous disease which was first adequately described by Vandyke Carter. He encountered it as an endemic infection in and around the city of Madura in the Madras Presidency of India. Since then it has been recognized in different parts of the world, including other districts in India, Ceylon, Cochin China, the Netherland East Indies, Africa, Argentina, Cuba, the United States and Canada. It occurs oftenest in arid tropical or subtropical climates among men engaged in agricultural pursuits who are in the habit of working barefoot. The disease is seldom seen in women. One of the commonest modes of infection is through the pricks of thorns. Unlike actinomycosis, which is most frequently found in cattle and swine, maduromycosis is apparently confined to human beings.

The case presented in this report appears to be the first example of maduromycosis of the hand to be described in the United States, the second on the North American continent and the fifth thus far recorded. It is probable that additional cases have been observed in this and other parts of the world but not recorded.

Experimental staphylococcic infections in animals which simulate natural-occurring infections in human beings are difficult to produce, according to Kempf and Herrick.[198] In order to evaluate the recently

196. Symmers, D.: Experimental Reproduction of Maduromycotic Lesion in Rabbits, Arch. Path. **39**:358-363 (June) 1945.

197. Symmers, D., and Sporer, A.: Maduromycosis of the Hand, Arch. Path. **37**:309-318 (May) 1944.

198. Kempf, J. E., and Herrick, J. A.: Effect of Penicillin on Experimental Staphylococcus Osteomyelitis in Rats, Proc. Soc. Exper. Biol. & Med. **58**:100-102 (Jan.) 1945.

introduced chemotherapeutic agents it would be desirable to have access to readily reproducible in vivo procedures. The purpose of this study was to develop methods for the production of chronic staphylococcic infections in mice and determine the value of penicillin in the treatment of such infections.

The results indicate that penicillin has definite value as a systemic therapeutic agent for staphylococcic osteomyelitis in rats and, further, that rats are suitable animals for studying the course of experimental osteomyelitis and the evaluation of therapy in this disease.

Osteomyelitis was produced experimentally in white rats by inoculation of the bone marrow of the tibia with Staph. aureus. About twenty-one days were allowed for the development of typical lesions. One group of 14 animals was treated by the subcutaneous injection of 600 units of penicillin every two hours for nine days. Six of these apparently recovered during the course of the treatment. In a second experiment 13 animals were each given 900 units of the drug every hour for an equal period. Again six of the lesions were found to be healed at the termination of the injections. Of a total of 25 untreated controls, only 1 animal showed evidence of recovery.

Mayers [199] reports a case of regeneration of bone following osteomyelitis. The patient was a policeman who was bitten on the middle finger of his left hand by a man whom he was arresting. Striking another person on the teeth by accident would seem to be less risky than a deliberate bite, but even such accidental contacts are not an infrequent source of infection, and there have been cases in which a mixed anaerobic infection from organisms of the mouth resulted. The latter was true in this case. Pyogenic organisms, spirilla and anaerobes were all present as the infection progressed.

The policeman was admitted to the hospital the morning after the wound was received. The following day the finger was incised below the nail, liberating a quantity of foul, purulent material. Drainage continued to be rather profuse for some time. The destructive process was advancing. Twelve days after the patient was admitted to the hospital the roentgenologist's report showed almost complete dissolution of the middle portion of the phalanx and tip, with moderately advanced invasion of the distal three fourths of the middle phalanx, and involvement of the distal joint; the soft tissues still showed considerable thickening.

Thus, it appears that the infection was advancing according to rule—from the distal anterior closed space by way of the nutrient foramen into the medullary cavity, with osteomyelitis as the result. Thence the

199. Mayers, L. H.: Bone Regeneration Following Osteomyelitis, Surgery **17**:463-471 (March) 1945.

spread is to the flexor subtendinous space of the base of the distal phalanx and into the joint cavity and continuing to the middle phalanx, with probably entry to the tendon sheath. In the case under discussion there was involvement of (1) soft tissue, (2) bone, (3) joint and (4) tendon.

The outcome of such a destructive and progressive osteomyelitis will depend on a number of things—the type of the organisms present, the age and condition of the patient and, probably most important of all, the treatment.

The mixed infection, particularly one including anaerobes, is more serious than one involving a single organism. A child has a better chance to combat the infection and to obtain regeneration of bone than an older person. The results in the case of the policeman, however, indicate that his age did not work against him. His recuperative power was one of the factors that gave the case a lively interest.

Jern and Meleney [200] note that the most important groups of bacteria from the point of view of surgeons are and always have been the streptococci, the staphylococci and the gram-positive spore-forming anaerobes of the gas gangrene group. It is generally recognized that the sulfonamide drugs have taken the terror out of hemolytic streptococcic infections and have reduced the incidence of septicemia from this organism to almost negligible proportions. It was hoped that they would be equally potent against the other two groups, but experience has shown that, while conditions in individual cases may respond promptly and remarkably, in the great proportion of cases they resist sulfonamide treatment.

Penicillin is outstanding in saving chick embryos or prolonging life after inoculation with virulent hemolytic Staph. aureus cultures in doses which regularly kill controls in twenty-four hours. In this respect it is superior to staphylococcus bacteriophage or staphylococcus antitoxin or vioform, or carboxymethoxylamine or sulfathiazole or another antibiotic derived from Bacillus T.

The increasing availability of penicillin and its demonstrated efficiency in the clinical treatment of staphylococcic infections relegates the use of staphylococcus bacteriophage in these infections to a place of second rank and only to be considered in cases in which penicillin fails.

The efforts of Jern and Meleney to produce a more highly potent staphylococcus phage by the use of egg embryos has not been successful. The difficulties of developing a commercial phage of high potency and

200. Jern, H. Z., and Meleney, F. L.: Superiority of Penicillin over Bacteriophage, Sulfathiazole and Certain Other Antibacterial Substances, Surg., Gynec. & Obst. **80**:27-34 (Jan.) 1945.

prolonged activity still remain. Further studies are indicated in the field of antibiotics for the staphylococcus and other organisms. Egg embryos offer a reliable medium for the appraisal of antistaphylococcus agents and other antibacterial substances.

Jern and his associates [201] point out that the treatment and prevention of chronic staphylococcic infections, particularly of recurrent furunculosis and axillary abscesses, have always been one of the major problems confronting general practitioners and surgeons. It is known that the use of vaccines, various chemicals and sulfanilamide derivatives, roentgenologic and ultraviolet irradiation, autochemotherapy and many other methods of treatment have not fulfilled their expectations. It is natural, therefore, that the discovery of staphylococcus toxin and its ability to produce antitoxin attracted wide attention as a possible method of treatment and prevention of staphylococcic infections.

The discovery of Burnet that staphylococcus toxin could be detoxified by solution of formaldehyde without the loss of its antigenic power greatly simplified the matter of immunization. This led to the wide clinical use of a detoxified toxin known in different countries as toxoid or anatoxin.

The problem of recurrent staphylococcic infections in the form of furuncles and carbuncles frequently plagues general practitioners and surgeons. It is well known that certain persons are generally resistant and others generally susceptible to infections. Others who have been resistant suddenly become susceptible. No reliable test has been discovered to measure either the resistance or the susceptibility to staphylococcic infections, although many attempts have been made to find such a test. Normal persons do not have a high antihemolysin titer, and there must be some other element of immunity which is responsible for natural resistance. Many immunologists believe that it resides in the phagocytic power of the leukocytes, but this cannot be consistently demonstrated.

The treatment of 93 patients with recurrent furunculosis and axillary abscesses with pepsin digest Staphylococcus toxoid (Lederle Laboratories, Inc.) resulted in a complete recovery of only 38 per cent. In the other 62 per cent, recurrences developed within one year after the end of the treatment. Of the 70 patients who received at least seven injections of pepsin digest toxoid, the antihemolysin titer in 52 cases (74 per cent) ranged between 1 and 3 units and in 18 (26 per cent) it was between 3 and 10 units. Out of 40 patients with recurrent furunculosis and axillary abscesses treated with Staphylococcus toxoid

201. Jern, H. Z.; Caprarro, C., and Meleney, F. L.: Value of Staphylococcus Toxoid in the Treatment and Prevention of Chronic Staphylococcus Infections, Surgery **17**:363-378 (March) 1945.

(Connaught Antitoxin Laboratory) complete recovery occurred in 31 (78 per cent). In 9 others (22 per cent) recurrences developed within one year after the end of the treatment. In 5 of the cases the recurrences were milder than the conditions prior to the treatment. Of 29 patients tested after seven or more injections of Connaught toxoid, the antihemolysin titer of the serums in 23 (79 per cent) ranged between 4 and 12 units; only in 6 (21 per cent) was it 3 units or less. These are statistically significant differences. The antihemolysin test is not a strict measure of immunity, for there are exceptional cases in which the patient has a rise in titer and has recurrences and others in which the patients have no rise and yet seem to be cured. There may be some other immune factor which does not run strictly parallel with the antihemolysin titer which is of major importance but cannot be measured.

Staphylococcus toxoid made from toxigenic strains is able, by means of repeated injections, to increase the antihemolysin titer of the blood and to lessen significantly the incidence of recurrence of furuncles and carbuncles.

Keefer [202] expresses the belief that since many recent publications describing the effects of streptomycin have created so much interest and so many demands for it the medical profession and public should be informed of the arrangements now in effect to adjust the present limited supply to a program of clinical investigation.

The Committee on Chemotherapeutics and Other Agents of the National Research Council, at the request of the Civilian Production Administration and the Streptomycin Producers Advisory Committee is supervising an investigation of the clinical usefulness and possible toxicity of streptomycin. The primary interest of the committee in streptomycin is to determine its effectiveness and toxicity in certain infections which are not susceptible to treatment with sulfonamide drugs, penicillin and other therapeutic agents.

The introduction of streptomycin to the medical profession is so recent that much remains to be learned concerning limitations of its usefulness, methods of administration, dosage and toxicity. Most of the information obtained so far has issued from military and civilian hospitals as a result of clinical investigations which have been carried out under arrangements between producers of streptomycin and individual clinical investigators. Similar studies are being continued and amplified by the Committee on Chemotherapeutics and Other Agents of the National Research Council, and a fraction of the streptomycin is now being allocated to the committee for these purposes. It is placed

202. Keefer, C. S.: Official Statement Concerning Streptomycin, J. A. M. A. **131**:31 (May 4) 1946.

in charge of the chairman for distribution to those hospital physicians most competent to obtain the vitally needed information.

Diseases which are to be investigated with streptomycin by the committee are gram-negative bacillary infections of the genitourinary tract resistant to the sulfonamide drugs; gram-negative bacillary infections with bacteremia; Hemophilus influenzae infections, including meningitis, pneumonia, diseases of the middle ear and laryngotracheitis; pneumonia caused by Friedländer's bacillus (Klebsiella pneumoniae); typhoid; Salmonella infections (paratyphoid); acute brucellosis with bacteremia; tularemia, and bacterial endocarditis due to gram-negative bacilli. Diseases which are not being investigated by the committee at present are chronic idiopathic ulcerative colitis, lupus erythematosis acutus disseminatus, leukemia, cancer, fever of unknown cause, rheumatic fever and rheumatoid arthritis.

Foley [203] observes that osteomyelitis is one of the most tragic of diseases which can affect the children of any nation, and the number of adults who are primary sufferers from this disease is also suprising.

There are certain points about the causation of osteomyelitis which are perhaps not well known. First, the history given by the patients or their relatives is often misleading; with deliberate questioning it is found that the initial cause of the illness, a carbuncle, boil or infection of the respiratory tract, has been forgotten and healed three to four weeks before the identical organism produced the train of symptoms known as acute osteomyelitis.

Second, persistent septicemia of an apparently unknown origin is more likely than not to be due to osteomyelitis, and, alternatively, if septicemia is permitted to persist it will more probably than not give rise to osteomyelitis. In 6 cases, had penicillin not saved the life of the patient and given time and opportunity for the feeding focus to be discovered in one of the bones, the patient would have died with the cause of his malady unrecognized, for it is not usual for every bone in the body to be examined in the postmortem room by the pathologist.

Dr. J. Trueta reported the results in a series of 30 patients with acute osteomyelitis treated with penicillin over a period of eighteen months at the Wingfield Morris Orthopaedic Hospital.

A standard routine was adopted. Patients admitted without abscess formation were treated by penicillin alone; those with abscess at the focus were treated with penicillin and with surgical treatment, which included drilling of the bone and primary suture after evacuation of as much pus as possible. Immobilization of the affected part was always used. The results were encouraging. There was no death in the series. In no case did a metastatic focus or a local invasion of the joints develop

203. Foley, W. B.: Treatment of Acute Osteomyelitis with Penicillin, Proc. Roy. Soc. Med. **39**:371 (Feb.) 1946.

after admission. Seven patients were suitable for treatment with penicillin without operation; the remaining 23 required surgical treatment. Of these, 2, early in the series, were treated by aspiration alone and had extensive damage to the bone. One was readmitted ten months after onset, with an abscess connected with the involucrum. Of the twenty-one wounds, eighteen healed without sinus formation, one (unsutured) became secondarily infected and required drainage after healing and two with extensive damage to the bone on admission developed sinuses. Four sinuses persisted, two from undrained and two from drained abscesses. There was normal function in 28 of the 30 cases. The exceptions were a patient with osteomyelitis of the femur admitted with septic arthritis of the knee, in which the knee range was 5 to 90 degrees, and a patient with osteomyelitis of the humerus, of fulminating type, admitted thirty-six hours after onset, with involvement of the whole shaft of the humerus; there was full range of movement at the joints, but she was still in hospital thirteen months after onset, with a persistent sinus.

The results of the treatment of acute osteomyelitis with penicillin were so good that it is fair to say that the disease has been altered and that a new standard is now needed for the results. It is no longer right to congratulate oneself on a low rate of mortality, metastases, involvement of the joints and sinuses. There should be no such rate. Improvements will be obtained if patients can be admitted earlier, and, now that it is known that there is a cure for the disease if it is treated early, physicians should admit patients for treatment earlier than they have done hitherto; one should no longer wait for the appearance of an abscess. Early stages can be treated by penicillin alone, and the patients may leave the hospital, perfectly normal, after three weeks. For later stages, however, surgical treatment is still important, and it should include drilling of the bone and primary suture.

Foley concludes that penicillin therapy has reduced the mortality of acute osteomyelitis from 25 per cent to about 4 per cent; that if penicillin is used during the first few days of the disease complete resolution may occur; that, if resolution does not occur, then immobilization of the affected limb should be prolonged in patients with extensive involvement of the bone, and if operation is required secondary suture can be safely done at the end of a week. There is no longer any justification for the closed plaster treatment in this disease.

According to Niebauer,[204] malignant degeneration of the skin which lines sinus tracts is not always readily recognized as a complication of chronic osteomyelitis. The carcinomatous lesions are in some instances large, cauliflower-like epitheliomas extruding from the sinuses; however,

204. Niebauer, J. J.: Development of Squamous-Cell Carcinomata in the Sinus Tracts of Chronic Osteomyelitis, J. Bone & Joint Surg. **28**:103-112 (Jan.) 1946.

the more insidious variety, often unsuspected until the development of metastases, exists deep in the epithelized cavities. Stewart, Obermayer and Woolhandler reported a case in which cutaneous metastases occurred after the amputation of a thumb for chronic osteomyelitis. The pathologist's examination of the amputated phalanx then revealed the primary epithelioma.

Henderson and Swart reported on 5 cases of malignant lesions among 2,396 cases of chronic osteomyelitis. Benedict found 12 such cases among 2,400 cases of chronic osteomyelitis. The epithelization of draining sinuses in cancellous bone is well recognized. Milgram claimed that this is one cause of persistent drainage.

Bereston and Ney, in reviewing the literature, found that malignant changes usually developed in men between the ages of 40 and 60 years who have had draining sinuses of from twenty to fifty years' duration. The tibia, the femur and the bones of the foot are oftenest involved.

Amputation is usually the best method of treatment. Because of the existing infection, it is logical to perform a guillotine amputation as close to the involved area as may be done with safety. If enlarged lymph nodes are present and do not subside after the amputation, they should be excised, since they may contain metastatic carcinoma. Roentgen therapy may then be initiated. The prognosis following amputation is good, since there are few early metastatic lesions.

These 2 cases clearly illustrate several points in the diagnosis of squamous cell carcinoma arising from epithelized, chronic sinuses of bone. Both patients were in the age group in which this complication is found oftenest. In neither patient was the correct diagnosis obvious on clinical examination. The skin at the edges of the sinuses appeared irritated from the constant drainage. Microscopic examination of the tissue first removed showed only chronic inflammation. In fact, in case 1, an epithelioma on the unhealed amputation stump led to reexamination and the discovery of the tumor in the amputated portion. The specimen obtained by curettage in case 2 showed no epithelioma. Thus in suspected cases it is well for the surgeon to perform a biopsy under direct vision in the operating room and to select several suitable specimens for microscopic examination.

Both patients had tolerated their osteomyelitis well for many years. Their complaints of pain and profuse foul discharge were of several months' duration only. The first patient had a pathologic fracture of the femur and bleeding from the sinuses in his thigh. These findings are characteristic of carcinoma, developing in an epithelized osteomyelitic sinus tract.

Roentgenograms of these 2 patients, although not diagnostic in themselves, presented a provocative finding of small areas of destruction in the sclerotic bone surrounding the cavities, a picture which may be the result of extension of the carcinoma.

The results obtained in cases of chronic osteomyelitis treated with penicillin reported by Keir [205] were a great improvement over those previously gained in his unit without penicillin. The general condition of the patients after operation was much better than in the prepenicillin days; the nurses in the wards were particularly impressed by this factor.

In the only 3 cases in which the lesions did not heal, penicillin-resistant staphylococci were present after operation, and these lesions were still unhealed many weeks afterward, despite the fact that the staphylococci again became sensitive to penicillin. It appears possible that during the period of resistance to penicillin the organisms cause further infection and destruction of bones.

It was shown that once the staphylococci were eliminated the penicillin-resistant group, Escherichia coli, Pseudomonas pyocyanea and Proteus vulgaris, succumbed in a few weeks to such preparations as a mixture of acriflavine and sulfathiazole powder, "U F I" powder (a preparation of urea and iodine) and alternate dressings of the "U F I" powder and eusol (an antiseptic solution containing calcium chloride, calcium borate and hypochlorous acid compounds).

Local surgical treatment in conjunction with use of penicillin offers a definite hope of clearing the process in many cases of chronic infection of the bone. The local surgical treatment must be adequate, and care must be taken to remove all infected tissue and sequestrated bone; otherwise the local administration of penicillin is valueless.

There has been some doubt about the value of penicillin in the treatment of chronic sepsis of the bone. In this series, however, in 23 out of 26 cases the lesions healed, and they have remained healed for an average period of four and a half months; 19 of the patients have returned to work, including several doing hard manual labor. It appears, therefore, that penicillin has an important part to play in the general scheme of treatment of chronic osteomyelitis.

Agerholm and Trueta [206] report that penicillin has changed the course and prognosis of acute hematogenous osteomyelitis. It is no longer enough to compare the results with and without penicillin; a new standard is needed. Physicians must no longer congratulate themselves that any series shows a low mortality rate, a low rate of metastatic infection, a low rate of involvement of the joints or a low rate of sinuses. It should be deplored that there is any such rate. It is known that if a patient comes to treatment early enough it is possible with penicillin alone to cause complete resolution of the lesion, and the patient may be discharged from hospital without any disability, perhaps at the end of

205. Keir, D. M.: Penicillin in Chronic Osteomyelitis, Lancet **2**:42 (July 14) 1945.

206. Agerholm, M., and Trueta, J.: Acute Haematogenous Osteomyelitis Treated with Penicillin, Lancet **1**:877-881 (June 15) 1946.

three weeks. The only regret in these cases is that so often there is no proof of the diagnosis, although there may have been no clinical doubt on admission.

In patients who come to treatment later, when there is already damage to the bone and abscess formation, there is some difference of opinion on the appropriate treatment. Agerholm and Trueta treated 2 patients of this type with penicillin and immobilization alone. They found that the systemic infection was controlled but that, even after all general disturbance had subsided, there remained local swelling and that roentgenographic changes spread from the original small focus at the metaphysis to involve half the shaft of the femur. They therefore abandoned this method of treatment and combined penicillin treatment with operation, which included drilling of the bone. The results were as good as they had hoped; the systemic response was more immediate, and there was no spreading roentgenographic change. Repair began in the area first shown roentgenographically to be involved; there was no spread of the disease to a neighboring bone or joint. The results contrasted so favorably with those of the undrained or undrilled infections that they did not feel justified in withholding operation from any more patients of this type. One patient was admitted eight weeks after onset from another hospital, where she had had two weeks' adequate penicillin therapy and incision of abscesses without drilling. She showed the same extensive damage to the bone seen in undrained infections; she also had severe anemia (hemoglobin content 42 per cent). Her general condition contrasted strongly with that of patients in the authors' series, though there was no evidence that the infection had initially been severer.

Two well defined groups of patients were distinguished: (1) those admitted before the bone was seriously damaged and before pus had formed and (2) those admitted with an abscess already present. Group 1 could be treated successfully by systemic penicillin alone, provided the course was sufficiently long and intensive; the condition might resolve without any roentgenographic changes in the bone; 7 out of 30 (1 in 4) patients admitted were suitable for this treatment. Group 2 must be treated surgically as well as with penicillin, and surgical treatment must include release of pus in the bone by drilling; after this, primary suture is safe and advisable to prevent secondary infection. In patients in group 2 not treated by operation as well as penicillin a spreading decalcification of the bone developed, the area of which increased over one to five months. Workers at other centers have confirmed this. In this series there was no death, no involvement of the joints and no secondary focus after admission. At the end of eighteen months, 4 patients had a sinus, but 2 of these were nearly healed; 28 patients had normal function; 1 patient admitted with septic arthritis of the knee had limited range of movement, and 1 had a sinus which kept her in hospital.

The importance of surgical drainage in these cases is discussed.

One case of infection with a penicillin-resistant organism was encountered early in this series but was not included in the series because at the time the authors did not have sufficient penicillin for adequate treatment of the patient. It was four times as resistant as the normal staphylococcus; it would have required at least 400,000 units of penicillin in twenty-four hours for bacteriostasis. The case serves as a reminder that the sensitivity of the organism must always be tested.

IX. CHRONIC ARTHRITIS

Prepared by
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NO OUTSTANDING discoveries have appeared in regard to chronic arthritis. There have been some additional studies on etiology. Gold therapy has been subjected to a somewhat more critical analysis, and the toxicity especially has been stressed. Reiter's syndrome has been frequently recognized, particularly in men in the Army. Here it has frequently been confused with gonorrheal infection, until bacteriologic studies giving normal results have questioned the diagnosis. Some excellent papers on general treatment have appeared. There has been greater interest in the surgical therapy of chronic arthritis, particularly osteoarthritis.

ETIOLOGY

A large number of trivial injuries occurring during a day's activities are regarded by Cecil [207] to be of importance in the pathogenesis of rheumatoid arthritis, particularly psychic trauma and strain. Poor posture is one of the factors causing daily mild trauma. When pains develop, rest and mild sedation may be enough. Often if the condition is not serious or likely to increase one must endure it philosophically. Proper readjustment of the environment will often correct what is not arthritis.

Edström [208] has observed that parts of the body which are not used are little involved by arthritis. Subcutaneous nodules appear where pressure and weight are borne. In arthritis after mechanical or functional damage the proliferative component becomes dominant.

Flind and Barber [209] studied 120 patients with articular pains at the Rheumatic Center of the Royal Air Force. Psychologic investi-

207. Cecil, R. L.: Environmental Factors in the Etiology and Pathogenesis of Rheumatism, M. Clin. North America **29**:566-570 (May) 1945.

208. Edström, G.: Relation Between Trauma and Arthritis, Acta med. Scandinav. **111**:150-171, 1942.

209. Flind, J., and Barber, H. S.: Psychogenic Basis of Some So-Called Rheumatic Pains, Quart. J. Med. **14**:57-74 (April) 1945.

gation was carried out on 42. There was a suggestive history of neurosis in 29 and a morbid concern over health in 26. There was often a family environment of chronic illness. In 8 there was a frequent change of employment. There was little evidence of rheumatic infection on physical examination. Hysterical reactions were found in 17, anxiety states in 22 and depressive states in 3. The diagnosis was usually difficult. Short psychiatric treatment was given in most cases. About 50 per cent of these patients were invalided. The authors questioned what name to give the conditions in these cases. They labeled each condition by its psychiatric diagnosis.

A characteristic basic vascular tone was found in patients with rheumatoid arthritis by Naide and associates.[210] There is consistently a high grade of basal vascular tone. Fifteen ambulatory patients with rheumatoid arthritis were studied. The peripheral vessels were constricted easily. The decided vascular tone may predispose to rheumatoid arthritis. The authors felt that this is a possible therapeutic lead and that attempts to produce reflex vasodilatation might be of benefit.

Sjövall [211] studied 116 cases of chronic polyarthritis in women and 47 nonarthritic women as controls in an attempt to find a relationship between sexual function and arthritic disease. Determinations of chronic gonadotropin levels were made in 102 women; estrone levels were measured in 14; both were measured in 3. Sjövall found that one third of the arthritic women under 40 had ovarian insufficiency. A relationship with chronic arthritis was observed in one fourth of them. The author postulated that ovarian insufficiency led to lessened follicular production but decreased estrone levels could be present with normal ovarian function. In pregnancy production of estrone was greatly increased. He found improvement in the arthritis in pregnancy in about one half of the cases.

[Ed. Note.—There was no mention of treatment with ovarian hormones.]

Admitting that the infectious theory for the causation of arthritis is unproved, Ensign [212] feels, however, that there is a formidible mass of evidence in favor of it in rheumatoid and in mixed forms of arthritis. Arthritis does not clear up on the removal of focal infection alone. The author advises complete examination of the mouth even when full den-

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210. Naide, M.; Sayen, A., and Comroe, B. I.: Characteristic Vascular Pattern in Patients with Rheumatoid Arthritis, Arch. Int. Med. **76**:139-142 (Sept.) 1945.

211. Sjövall, H.: Hormone Excretion in Chronic Polyarthritis of Female: Relation Between Sexual Function and Articular Diseases in Women, Acta med. Scandinav. **117**:69-89, 1944.

212. Ensign, D. C.: Oral Focal Infection: Status Today, J. Oral Surg. **3**:89-101 (April) 1945.

tures are worn. Often fragment of roots are still present. Pulpless teeth should be watched. Teeth which show a radiolucent area may show infection. When extractions are performed sulfonamide drugs should be given before and at least twenty-four hours after extraction.

[ED. NOTE.—Rheumatoid arthritis remains a disease of uncertain cause. One is left with the necessity of considering all functional deviations of etiologic importance and of regarding their correction to be of possible therapeutic value.]

Meyer [213] states that all oral infection tends to spread into the venous system, especially the jugular vein. After complete removal of oral infections the infection in the jugular veins disappears in some cases, but in most instances it persists as a latent focus of infection. He feels that this focus can play an important role in the production of rheumatic disease.

Mucoid hemolytic streptococci which are responsible in milk-borne epidemics of sore throat are found in less than 1 per cent of persons. Pilot [214] states that they are often found in the throat in rheumatic conditions. They are readily identified on brain-heart infusion blood agar plates. These organisms may disappear spontaneously or after the removal of the tonsils, with relief of the arthritic symptoms.

TESTS

Steinberg and Lowenstein [215] observed the Weltmann reaction in 111 patients, 44 with rheumatoid arthritis, 27 with osteoarthritis and the remainder with other rheumatic diseases. Most patients suffering from arthritis showed a shift to the right above 7.5 in the Weltmann reaction. This test was of no value in the differential diagnosis of the various arthritic disorders There was a definite relationship between the severity of the clinical symptoms and the degree of shift to the right of the Weltmann reaction. The reaction, in their opinion, is of definite prognostic value.

DIAGNOSIS

Fletcher and Lewis-Faning made a statistical study of 1,000 cases of chronic arthritis.[216] There was more rheumatoid arthritis in women. Gout, fibrositis and sciatica were commoner in men. The age distribution was the same in both sexes. Heavy laborers were prone to have

213. Meyer, O.: Mechanism of Oral Focal Infection, M. Rec. **158**:604-606 (Oct.) 1945.

214. Pilot, I.: Role of Mucoid Hemolytic Streptococci in Arthritis, Proc. Central Soc. Clin. Research **17**:70-71, 1944.

215. Steinberg, C. L., and Lowenstein, F. W.: Weltmann Reaction in Arthritis, Am. J. Clin. Path. **15**:395-401 (Sept.) 1945.

216. Fletcher, E., and Lewis-Faning, E.: Statistical Study of 1,000 Cases of Chronic Rheumatism, Post-Grad. M. J. **21**:137 (April); 176 (May) 1945.

osteoarthritis develop. Clerks showed an excess of spondylitis. Obesity and hypertension were common in osteoarthritis. A blood sedimentation rate over 50 mm. per hour was usually found in active arthritis.

The present classification of arthritis is unwieldy. Wilson [217] finds that 95 per cent of all cases fit into the following classification: (1) rheumatoid arthritis, chiefly synovitis; (2) osteoarthritis, chiefly a degeneration of the cartilage; (3) traumatic arthritis with or without degeneration of the cartilage; (4) specific infectious arthritis, often synovitis; (5) acute rheumatic fever, probably an allergic response in articular tissue, and (6) gouty arthritis.

Chronic monarticular arthritis is often [218] difficult to diagnose. Diagnosis sometimes can be made only by watching the course of the disease. Fourteen cases with monarticular symptoms six months or longer were followed for periods varying from two to fifteen years. Only 2 of these proved to be cases of rheumatoid arthritis. Chronic monarticular arthritis is found in less than 0.5 per cent of the cases seen in an arthritic clinic. Surgical procedures or any treatment which may prove harmful should be avoided until a diagnosis can be made. Pain, however, should be relieved, deformity should be prevented and the joint should be protected while a diagnosis is being made.

Ropes and Bauer [219] state that in rheumatoid arthritis, as in all chronic disease, there are varied manifestations. Many nonarticular structures are involved. Usually there are prodromal symptoms, with an insidious onset and a slowly progressive course. It may resemble an acute infection at the beginning. Illustrative cases are reported of rheumatic fever, traumatic arthritis with articular derangement, ruptured intervertebral disk, psychoneurosis, fibrositis and intermittent hydrarthrosis, in which diagnosis could not be made immediately.

The first act in chronic arthritis is to establish a diagnosis.[220] One should not depend too much on the sedimentation rate and the roentgenogram. Improvement is usually not continuous. The patient must be treated as well as the joint. The affected joints should not be used too much. One must not expect too much from physical therapy. Gold salts must be given cautiously. In many instances the patient need not give up his job.

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217. Wilson, C. P.: Arthritis: A Workable Classification, Northwest Med. **44**:7-9 (Jan.) 1945.

218. Kuhns, J. G.: Chronic Monarticular Arthritis, New England J. Med. **232**:128-132 (Feb. 1) 1945.

219. Ropes, M. W., and Bauer, W.: Varied Clinical Manifestations in Rheumatoid Arthritis, New England J. Med. **233**:592 (Nov. 15); 618 (Nov. 22) 1945.

220. Comroe, B. I.: Common Mistakes in the Handling of Patients with Arthritis and Allied Conditions, J. A. M. A. **127**:392-396 (Feb. 17) 1945.

[ED. NOTE.—As more conditions are discovered which at times present articular inflammation, the diagnosis of rheumatoid arthritis is made with greater caution. Diagnosis is usually made by observing the course of the disease. Laboratory tests are merely confirmatory.]

REITER'S SYNDROME

Reiter's syndrome, described by Reiter in 1916, with the triad of arthritis, conjunctivitis and urethritis, was observed frequently in the armed forces, and, as one would expect, it was frequently confused temporarily with acute gonorrheal infections. It has not yet found its place in the classification of arthritis.

Twenty-five cases of this disease are reported from the Ashburn General Hospital.[221] Eleven of the patients had arthritis, conjunctivitis and urethritis, and 14 failed to have conjunctivitis. There was an explosive onset in all cases. Aspiration of joints was carried out in 8. Changes in the roentgenograms, chiefly osteoporosis, were found in 18; periosteal proliferation was seen in 3. The acute stage usually lasted four to six weeks. Most of the patients became asymptomatic in three months, but a few continued to have symptoms after eight months. An arthrotomy in 1 patient in the eighth month showed intense inflammation in the synovial membrane but no change in the cartilage. It seemed to be a self-limited disease without residual damage. Rosenblum [222] states that the conjunctivitis and urethritis are transient (weeks), while the arthritis lasts longer (two to three months). Sulfonamide drugs and penicillin have no effect. The symptoms may recur. Roentgenograms are noncontributory, and laboratory studies show nothing except a mild leukocytosis.

The histories of the cases of 2 young men with Reiter's disease are given by Miller and McIntyre [223] with a review of the literature. They state that rest is the only therapy. Administration of penicillin is useless. Full recovery occurs.

Colby [224] studied a 21 year old student with this syndrome. No organisms were found. Sulfanilamide was given, with questionable benefit. There was no remaining disability. A second patient, a 26 year old workman, had hematuria. The urine was sterile, but the right

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221. Hollander, J. L.; Fogarty, C. W., Jr.; Abrams, N. R., and Kydd, D. M.: Arthritis Resembling Reiter's Syndrome: Twenty-Five Cases, J. A. M. A. **129**: 593-595 (Oct. 27) 1945.

222. Rosenblum, H. H.: So-Called Reiter's Disease: Triad of Acute Arthritis, Conjunctivitis and Urethritis, U. S. Nav. M. Bull. **44**:375-378 (Feb.) 1945.

223. Miller, C. D., and McIntyre, D. W.: Reiter's Disease: Urethritis, Conjunctivitis and Arthritis, Ann. Int. Med. **23**:673-682 (Oct.) 1945.

224. Colby, F. H.: Renal Complications in Reiter's Disease, Tr. Am. A. Genito-Urin. Surgeons (1944) **37**:93-98, 1945.

kidney, which was hydronephrotic, was removed. The hematuria disappeared, but the patient had recurrent attacks four years later. A third patient, a 26 year old physician, had sterile urine, but hematuria improved with dilatation of both renal pelves. The author felt that renal pathologic changes should always be looked for in this disease.

Improvement in Reiter's disease followed the injection of 10 cc. of boiled milk in a 38 year old man.[225] The arthritis improved following this induced pyrexia but still persisted. The other symptoms disappeared. This therapy was repeated in six days with the injection of 6 cc. of boiled milk. After this all symptoms disappeared. The patient was still free from symptoms eight months later.

GOUT

Ficarra and Adams [226] found that endogenous uric acid from a breakdown of nuclear material could cause a rise in blood uric acid content. Five patients were reported with postoperative gouty arthritis. All these patients were over 55 years of age and had osteoarthritis. The symptoms of gout appeared within five days after operation. The great toe was usually involved. Hypoproteinemia was present in 4, and hyperuricemia was present in all. Hyperproteinemia stimulates endogenous purine metabolism. This complication can best be avoided by administration of adequate amounts of protein postoperatively.

Of 168 cases of polycythemia vera, the conditions in 8 were complicated by gout.[227] This condition may occur from the breakdown of cells which are the endogenous precursors of uric acid. This breakdown of cells may make mild gout severe or can make a case of severe gout difficult to control.

Hertzberg [228] finds that alkaptonuria with ochronosis produces lesions in bone similar to osteoarthritis. The pigment is deposited in cartilage, and this is followed by friability of the cartilage. The articular capsule becomes thickened, and small fragments of cartilage are buried in it. The history of a case is reported of a 54 year old fisherman with ochronosis and lesions in the left shoulder and both knees. An arthrotomy of the left knee was performed. Pigment was found in the synovial membrane and in the articular cartilage.

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225. Strachstein, A.: Reiter's Disease: Case Successfully Treated, New York State J. Med. **45**:2190-2191 (Oct. 15) 1945.

226. Ficarra, B. J., and Adams, R.: Postoperative Gouty Arthritis, Arch. Surg. **50**:229-232 (May) 1945.

227. Tinney, W. S.; Polley, H. F.; Hall, B. E., and Giffin, H. Z.: Polycythemia Vera and Gout, Proc. Staff Meet., Mayo Clin. **20**:49-55 (Feb. 21) 1945.

228. Hertzberg, J.: Osteoarthritis Alkaptonurica (Ochronotica), Acta radiol. **26**:484-490, 1945.

Neligan,[229] in discussing the management of osteoarthritis, states that the cooperation of the patient is vital. The involved joints should be spared. All mechanical, metabolic and endocrine disturbances should be corrected. Work should be carried out for short periods at a time. The job should be fitted to the person. Reduction in weight may be necessary. Function, however, should be maintained. There should be active stretching and active training of special muscles. Physical therapy consists of local heat, diathermy, pool treatment, massage and exercises. Persistent pain in the joint usually is not due to osteoarthritis. In severe osteoarthritis operative fixation of the joint may be required. Occasionally salicylates, iodine and thyroid are helpful.

In conclusion he gives a five point program: 1. Secure the cooperation of the patient. 2. Insure the best possible environment. 3. Remove any recognized etiologic factors. 4. Maintain function as much as possible. 5. Relieve pain.

Hendry[230] considers osteoarthritis to be an orthopedic problem chiefly. The helpful general measures are elimination of focal sepsis, correction of chronic constipation and reduction of obesity. As preventive measures he lists the teaching of proper weight bearing and posture (the correction of upset joint axes) and improvement of muscular weakness. Joints with a minimal amount of change may be manipulated, preferably by repeated small manipulations. Rest and external fixation, either complete or by a spica, are useful temporary measures. A raised heel is sometimes required. Débridement of the joint, arthrodesis and arthroplasty have little place in the treatment of osteoarthritis. Osteotomy is at times of value.

[ED. NOTE.—The author does not give the indications for the various measures recommended.]

In a symposium on the treatment of unilateral osteoarthritis of the hip, Girdlestone[231] advocates surgical therapy when there is severe crippling. The operation should be adapted to the patient to provide the most useful hip. One has to consider pseudarthrosis, arthrodesis, arthroplasty, osteotomy and reconstruction in planning the treatment. Watson-Jones felt that arthrodesis of the hip with a flanged nail was the most effective therapy. Simple removal of articular cartilage usually led to failure. He reported that one hundred and thirty-five arthrodeses had been performed for osteoarthritis. Arthroplasty was advocated only in

229. Neligan, A. R.: Management of Osteoarthritis, Proc. Roy. Soc. Med. **38**:208-210 (March) 1945.

230. Hendry, A. M.: Osteoarthritis as an Orthopedic Problem, Practitioner **155**:89-94 (Aug.) 1945.

231. Girdlestone, G. R.; Watson-Jones, R.; Stamm, T. T., and Prindie, K. H.: Discussion on the Treatment of Unilateral Osteoarthritis of Hip Joint, Proc. Roy. Soc. Med. **38**:363-368 (May) 1945.

severe bilateral osteoarthritis. Stamm stated that arthroplasty found its chief usefulness in bilateral osteoarthritis. A metallic cup could be used, or a simple new joint could be designed. Pridie reported that he had performed one hundred and twenty-one operations (no statistics given). He found the cause of pain to be most often a shallow hip or aseptic necrosis of the femoral head.

RHEUMATOID ARTHRITIS OF THE SPINE

Mennell,[232] in discussing ankylosing spondylitis, states that it usually first appeared in three distinct age periods: in adolescents of 17 to 21 years, in young adults of 25 to 30 years and occasionally in older groups. Early roentgenograms will show sacroiliitis. Roentgen ray therapy offers the only prospect of improvement. This can be given as wide field or as local therapy. He feels that a plaster jacket is harmful.

Early diagnosis is made with difficulty in the prespondylitic phase, when only vague pains are present, according to Dekkers.[233] Later there is sacroiliitis with constant pain, followed by the poker back deformity. Diagnosis is often made only three to six years after the onset. The peripheral and the spinal joints should be considered as one morbid entity. Spondylitis usually does not react well to gold treatment. McWhirter [234] states that little or nothing can be done when the disease is far advanced. In his group it usually first appeared in the third decade. Ninety-one per cent were males in a group of 162. It was often treated at first for fibrositis or lumbago. Biopsy specimens to determine the stage of the disease process were readily obtained at the articulation between the manubrium and the body of the sternum. The lesions in the spine suggest a similar distribution to those seen in metastases from carcinoma of the prostate. The first treatment should be roentgen ray treatment up to 2,500 r units. He advises desoxycorticosterone acetate and increased salt content in the diet for roentgen ray sickness. Roentgen ray treatment alone is not adequate. In early cases there should also be physical therapy with deep breathing exercises. A brace is used when the patient gets up. In more advanced conditions a light plaster jacket is used for six to twelve months. In advanced cases a jacket is worn for support indefinitely.

[ED. NOTE.—In this problem of support to the spine one should be guided by the clinical indications. If there is acute pain on any motion

232. Mennell, J. M.: Ankylosing Spondylitis, M. Press **212**:378-380 (Dec. 13) 1944.

233. Dekkers, H. J. N.: Spondylarthritis Ankylopoetica (Spondylosis Rhizomelica) Combined with Peripheral Arthritis, Acta med. Scandinav. **113**:506-526, 1943.

234. McWhirter, R.: Ankylosing Spondylitis, Brit. J. Radiol. **18**:302-305 (Oct.) 1945.

a rigid support which immobilizes the spine is required. Later, when pain subsides, support should be used only to prevent deformity. All support should be discarded when there is no further tendency to forward bowing. Many patients, however, are never comfortable without spinal support.]

A relationship between changes in the cervical spinal articulations and the Barré-Lieou syndrome is postulated by Jonsson.[235] Headache, faintness and varying symptoms in the eyes and ears were found, usually associated with changes in the cervical vertebrae, particularly in the vertebral joints. One patient with this syndrome died, and the cervical portion of the spine showed no compression of the vertebral canal. He states the belief that these symptoms originate in the sympathetic nerves.

In 2 cases of advanced spondylarthritis, pieces of thyrotoxic goiter were implanted in the posterior rectus sheath. This was followed by improvement. The author [236] expresses the opinion that there was no direct relationship but that the improvement came from the increased basal metabolism. In 2 cases of less severe conditions, thyroxin was given and improvement resulted.

Wyatt [237] advocates twenty treatments of 33 r units plus exercises for ankylosing spondylitis. The sedimentation rate is raised at first when treatment is given, but it goes down later. Improvement usually follows this treatment. One hundred and sixty patients with arthritis of the spine at Duke University [238] were given roentgen ray treatment. One hundred and twenty-three were between 20 to 39 years of age; 40 of these patients were seen with the condition in an early stage, in 58 it was moderately advanced and in 38 it was far advanced. With a combination of orthopedic treatment and roentgen ray treatment 76 per cent improved. Women must be treated with caution and with smaller dosage. Vomiting following roentgen ray therapy can be helped by giving tablets of vitamin B_6. Repeated series of roentgen rays are given if the sedimentation rate is increased and symptoms become worse. Twenty per cent of 99 patients reported in a follow-up letter that they were free of symptoms one year after roentgen ray treatment. The best results are obtained when roentgen ray treatment is given early.

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235. Jonsson, E.: Changes in the Uncovertebral Joints of the Cervical Spine in Relation to Barré-Lieou Syndrome, Acta chir. Scandinav. **87**:154-168, 1942.

236. Mandl, F.: Attempts to Influence Spondylarthritis Ankylopoietica by Means of Implantation of Toxic Goitre, J. Internat. Coll. Surgeons **6**:529-536 (Nov.-Dec.) 1943.

237. Wyatt, H.: Ankylosing Spondylitis, Brit. J. Radiol. **18**:301-302, (Oct.) 1945.

238. Hemphill, J. E., and Reeves, R. J.: Roentgen Irradiation in the Treatment of Marie-Strümpell Disease (Ankylosing Spondylarthritis): Analysis of One Hundred and Sixty Cases, Am. J. Roentgenol. **54**:282-289 (Sept.) 1945.

SURGICAL TREATMENT

Batchelor [239] advocates excision of the femoral head and neck in the presence of ankylosis of the hip in arthritis. This leads to potential instability. Calipers must often be used for months. A subsequent Schanz osteotomy was required in 2 cases. Both procedures can be carried out at the same time by the use of a bent plate. These procedures relieve pain and permit motion.

Karlén [240] had performed sixteen arthroplasties for osteoarthritis of the hip by 1943. Of these, seven were carried out with fascial transplants, and a vitallium cup was used in nine. The results of two of the fascial arthroplasties were good, and the results of three were good with vitallium cups. Three fascial arthroplasties gave fair results. Results of two fascial arthroplasties were poor, and six vitallium cup arthroplasties gave poor results. One vitallium cup arthroplasty was too recent for report. The author felt that the chances of a good result following arthroplasty in arthritis deformans were slight. Good results were not achieved after patients were 30 years. Such operations were not for persons who had to follow a strenuous occupation.

The late results of arthroplasty for ankylosis of the hip are reviewed by Langenskiöld.[241] Most such attempts at forming a new joint should more properly be called arthrolysis. Of 15 cases, the reasons for operation were bilateral ankylosis in 3, ankylosis in faulty position in 11 and inability to carry out coitus in 1. The articular surfaces were reshaped, and fascia was interposed. The criteria of Campbell were used in studying the end results. In 3 they were excellent, with motion between 50 degrees and 160 degrees, in 3 they were good and in 1 they were doubtful. The author could not prognosticate from the nature of the lesion whether ankylosis would recur. Ankylosis recurred in 8 cases. In 1 case total destruction of the head and neck occurred on both sides ten years after arthroplasty for gonorrheal arthritis. This operation has been recommended with caution since 1926.

[ED. NOTE.—The editor has noticed during the past five years that many of these newly formed joints wear out with great rapidity. It may be that the bone in chronic arthritis is less resistant to continued use. Even in non-weight-bearing joints, subluxation or persistent pain and stiffness are common occurrences after five to ten years of use.]

239. Batchelor, J. S.: Excision of the Femoral Head and Neck in Cases of Ankylosis of the Hip, Proc. Roy. Soc. Med. **38**:689-690 (Oct.) 1945.

240. Karlén, A.: Arthroplasty in Arthritis Deformans, Acta med. Scandinav. **90**:482-494, 1944.

241. Langenskiöld, F.: Late Results of Arthroplasty in Ankylosis of the Hip, Acta chir. Scandinav. **91**:254-268, 1944.

Smith-Petersen and his associates describe a procedure for partial correction of flexion deformity of the spine [242] in ankylosing spondylitis. The bony ankylosis between the laminas and between the articular facets is freed with a chisel. Histories of 6 cases are reported showing some correction of the flexion deformity.

Arthroplasty of the first metatarsophalangeal joint is described by Crosby and Galasinski.[243] After the ends of the bones were reshaped, tantalum 0.015 inch (0.03 cm.) thick was shaped over a mold, and this was later sterilized and fitted over the metatarsal head. Active motion and freedom from pain were observed six months later.

THERAPY WITH GOLD COMPOUNDS

Block and Knapp [244] studied the in vitro effect of various gold compounds on the oxygen consumption of fresh slices of liver and kidney from healthy white rats. They found that the oxygen consumption was inhibited by inorganic ionizable compounds of gold, gold chloride and gold sodium thiosulfate. There was less inhibition by colloidal gold sulfide. Organic nonionizable compounds, sodium succinimidoaurate, gold sodium thiomalate and gold thioglucose did not cause any inhibition. Those compounds which did not have any effect on the oxygen consumption of tissue slices are the compounds which produce the least toxic effects.

In gold therapy one is treating a disease of unknown causation with a medium whose dosage and mode of action are obscure and whose toxic potentiality is unpredictable.[245] Cutaneous rashes are the commonest toxic reactions. Gold therapy is indicated only in rheumatoid arthritis in which there is an 80 per cent chance of improvement and a 0.5 per cent chance of dying from the drug.

Cohen and colleagues [246] review 259 patients who were treated with gold (aurothioglucose in oil). Objective improvement was observed in 88 per cent of these patients. There was one fatality from thrombo-

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242. Smith-Petersen, M. N.; Larson, C. B., and Aufranc, O. E.: Osteotomy for Correction of Flexion Deformity in Rheumatoid Arthritis of the Spine, J. Bone & Joint Surg. **27**:1-11 (Jan.) 1945.

243. Crosby, E. H., and Galasinski, R. E.: New Arthroplasty for Small Joints, Connecticut M. J. **9**:926-928 (Dec.) 1945.

244. Block, W. D., and Knapp, E. L.: Metabolism, Toxicity and Manner of Action of Gold Compounds in the Treatment of Arthritis: Effect of Various Gold Compounds on Oxygen Consumption of Rat Tissues, J. Pharmacol. & Exper. Therp. **83**:275-278 (April) 1945.

245. Lansbury, J.: Gold Therapy in Arthritis, Pennsylvania M. J. **47**:216-220 (Dec.) 1943.

246. Cohen, A.; Goldman, J., and Dubbs, A. W.: Treatment of Rheumatoid Arthritis with 417 Courses of Gold: Analysis of 259 Cases, New England J. Med. **233**:199-203 (Aug. 11) 1945.

cytopenic purpura. They found that 300 mg. of vitamin C daily or vitamin B complex daily did not lessen the number of toxic reactions. A normal sedimentation rate was no contraindication. Toxic reactions occurred in 10.3 per cent. Toxic reactions were more frequent in those receiving two or more courses of gold.

Comroe [247] states the belief that gold therapy is of value only in rheumatoid arthritis. It is not a specific therapy. Toxic reactions may appear at any time. Ten to 20 per cent of the patients relapse after gold treatment. While this treatment is often helpful, it must be given with caution. It should be used only after the usual conservative treatment fails. Gold is the only drug which shows promise of checking the disease. Its mode of action is unknown. The gold is excreted slowly. Much remains in tissues a long time. Colloidal gold usually shows neither toxic nor therapeutic benefits. The dosage in the usual course is 850 mg. of gold. It may be repeated in eight weeks.

A new gold preparation, Lauron (aurothioglycolanilide), containing 54 per cent gold, is given by intramuscular injection.[248] It is less toxic than the usual compounds used. Twenty-five to 300 mg. can be given. Fifty-five patients have been treated, but no results can be reported yet. Stengel [249] reports on 30 patients treated ten months or less with aurothioglycolanilide. The toxicity seems to be dependent on the radical to which the gold is attached. All the patients (rheumatoid arthritis) showed some improvement. The improvement was shown by less swelling in the joints in four to five weeks. In 4 patients conjunctivitis developed.

OTHER METHODS OF TREATMENT

Roentgen therapy was advocated as a local treatment only by Borak and Taylor.[250] Kaplan [251] treated 141 patients with arthritis with roentgen rays (no statistics are given); 100 to 200 r are given once or twice a week until the patient becomes comfortable. He expresses the opinion that the results are lasting. No harmful effects were observed.

Radon, the first product of disintegration of radium, was used to treat arthritis by Lustig.[252] Thirty-five patients were treated with radon

247. Comroe, B. I.: Abuse of Gold Therapy in Rheumatoid Arthritis, J. A. M. A. **128**:848-851 (July 21) 1945.

248. Robinson, D.: New Gold Preparation (Aurothioglycoanilid), Canad. M. A. J. **53**:279-280 (Sept.) 1945.

249. Stengel, E.: New Gold Compound (Aurothioglycoanilid), Bull. Hosp. Joint Dis. **5**:114-121 (Oct.) 1944.

250. Borak, J., and Taylor, H. K.: Beneficial Effects of Roentgen Therapy in Advanced Cases of Rheumatoid Arthritis, Radiology **45**:377-384 (Oct.) 1945.

251. Kaplan, I. I.: Roentgen Therapy of Arthritides, New York State J. Med. **45**:1339-1343 (June 15) 1945.

252. Lustig, F.: Radon and Physical Therapy in Arthritis, M. Rec. **158**: 225-228 (April) 1945.

ointment which contained 200 electrostatic units per cubic centimeter. Six treatments of 12,000 electrostatic units each were given. A certain amount of improvement was reported.

Danowski and colleagues [253] report 2 cases of renal damage secondary to prolonged treatment with large doses of vitamin D. One patient, a 47 year old housewife, took 150,000 to 200,000 units of vitamin D daily between 1936 and 1942. There was a fluctuant swelling on the left wrist and ankle containing chalky material. Albumin gradually disappeared from the urine, and blood calcium and phosphorus levels became normal. Later the chalky deposits disappeared. The second patient was a 56 year old woman who received 500,000 units of vitamin D for five months. There were hypertension and hypercalcemia and a urine of constant low specific gravity. There was poor excretion of phenolsulfonphthalein. They feel that administration of large doses of vitamin D demands careful supervision.

The effect of jaundice on arthritis was reviewed by Gardner and his associates.[254] Thirty-two patients with rheumatoid arthritis were inoculated with the virus of infectious jaundice. In 10 cases the conditions were mild, in 5 moderate, in 11 severe and in 6 extremely severe. Jaundice appeared after inoculation in twenty-seven to one hundred and thirty-one days. No change was observed during the incubation period. Remissions which followed the appearance of jaundice were variable and of short duration; 15 patients were completely free from pain and swelling, and 15 others showed improvement. The average period of improvement was forty-two days. There was no definite relationship between the intensity of the jaundice and the type of remission which was produced. The authors did not advocate this as a therapeutic measure and felt that it was justifiable only as a research project.

Penicillin injected intramuscularly in 7 cases of hydrarthrosis was demonstrated in the synovial fluid. The concentration of penicillin both in the blood serum and in the fluid in the joints was determined by the cup assay method.[255] The penicillin penetrated into the joint readily and left the articular cavity more slowly than the blood serum. A sufficient amount entered the joints with the usual dosage, 25,000 to 40,000 units every three hours, and attained levels in the articular cavity comparable to those in the blood serum.

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253. Danowski, T. S.; Winkler, A. W., and Peters, J. P.: Tissue Calcification and Renal Failure Produced by Massive Dose Vitamin D Therapy, Ann. Int. Med. **23**:22-29 (July) 1945.

254. Gardner, F.; Stewart, A., and MacCallum, F. O.: Therapeutic Effect of Induced Jaundice upon Rheumatoid Arthritis, Brit. M. J. **2**:677-680 (Nov. 17) 1945.

255. Balboni, V. G.; Shapiro, I. M., and Kydd, D. M.: Penetration of Penicillin into Joint Fluid Following Intramuscular Administration, Am. J. M. Sc. **210**:588-591 (Nov.) 1945.

GENERAL THERAPY

In a lecture on atrophic arthritis before the Glasgow Medical Society, Davidson [256] reviewed the various etiologic factors which have been suggested and gave an outline of treatment. Data were gathered from 388 patients. A diagnosis of rheumatoid arthritis was made by the presence of persistent periarticular swelling, involvement of wrist, metacarpophalangeal or interphalangeal joints, the presence of muscular wasting, absence of specific causation of the arthritis and roentgenologic evidence compatible with rheumatoid arthritis. In regard to heredity he found no proof of a predisposition to arthritis. There was no special body build. He expressed the opinion that the reduced incidence in the tropics was probably related to diet, housing temperature and infection. Environmental conditions increased the chance of cross infection and reduced the patient's resistance. There was no proof of any direct relationship to pregnancy.

The menopause did not tend to precipitate the onset of rheumatoid arthritis. No proof was obtained that a failure of absorption, utilization or excretion of any dietary factor was of primary etiologic importance. While an adequate ingestion of vitamins was advisable in any chronic disease, no proof was shown that vitamin deficiency led to arthritis. Disorders of the endocrine glands played no specific role, but the peripheral circulation and the permeability of the capillaries could be altered by the products of certain glands. While there were many features which favored the view that infection played some etiologic role there was no proof that it was an infectious disease. Infection had occurred within two months of the onset of arthritis in 12 per cent of the men and 21 per cent of the women. Focal sepsis was present in 38 per cent. The allergic hypothesis was accepted as a working basis for prophylaxis and treatment. This was supported by a great deal of experimental work in animals, and it gives an explanation of certain clinical findings.

Treatment should be of the whole patient in an attempt to raise his resistance. In regard to the general health, fatigue should be eliminated, pain reduced and psychologic factors removed. Special postural and breathing exercises should be given. Focal sepsis should be removed with sulfonamide drugs given at the same time. Attempts at desensitization should be reconsidered. The entire question of vaccines should be reviewed. Gold salts might be tried in small doses. Proper care should be given to the affected joints. Drugs should be used only as they are indicated.

256. Davidson, L. S. P.: Etiology and Treatment of Rheumatoid Arthritis, Tr. Roy. Med.-Chir. Soc. Glasgow, 1943-1944, pp. 2-5 and 6-16; in Glasgow M. J., December 1943 and January 1944.

Roland [257] states that the Veteran's Administration cannot care for all patients with arthritis in hospitals. Many must be cared for at home. Home treatment should include psychotherapy, occupational therapy and physical therapy. Mental changes take place in a chronically ill patient—depression and fear—so that the therapy is inadequate. Occupational therapy keeps the mind occupied and gains confidence. Graded activity and physical therapy are given to stimulate circulation, to prevent contractures and muscular wasting and to correct deformities.

Kovacs [258] discusses the uses and limitations of physical therapy in chronic arthritis. It is the oldest standby in therapeutics. Heat locally increases the circulation and tissue metabolism, relaxes spasm and relieves pain. The bath in liquid petrolatum is a useful local form. Short wave diathermy should be measured in dosage. Diathermy about the area of a focus of infection may increase the sedimentation rate temporarily. Artificial fever therapy is disappointing. There is only occasional improvement. Thermal effect with friction is particularly useful for the feet. Exercises under water are equally effective and can be used at home. Counterirritation, galvanic current and ionization are helpful for a time. If the physical therapy at home is supervised intelligently, it can be of great help.

MISCLLANEOUS

Hickam [259] gives the articular manifestations of lymphogranuloma venereum as arthralgia, acute polyarthritis, chronic recurrent polyarthritis, tenosynovitis and bursitis. Histories of 4 cases are reported in detail. He advises the use of a dilution of chick antigen in patients with active disease.

Arthralgia and myalgia are common at the onset of fever in meningococcic infections, but this is of little consequence.[260] Purulent arthritis occurs occasionally but is rare since sulfonamide compounds have been used. Histories of 2 cases of severe purulent polyarthritis are given. Operation is not indicated. The arthritis begins as an acute synovitis. Restoration of articular function commonly occurs.

Arthritis produced by the injection of silver nitrate into the tibiotarsal joints of rats was used to test synaptic transmissions in the soleus and tibialis anterior muscles.[261] The third stage of neuromuscular trans-

257. Roland, P. E.: Home Treatment Program for Chronic Arthritis, Occup. Therapy **24**:160-162 (Aug.) 1945.

258. Kovacs, R.: Newer Methods of Physical Therapy in Chronic Arthritis, Tr. Am. Therap. Soc. **42**:24-29, 1942.

259. Hickam, J. B.: Cutaneous and Articular Manifestations in Lymphogranuloma Venereum, Arch. Dermat. & Syph. **51**:330-336 (May) 1945.

260. Boger, W. P.: Purulent Meningococcal Arthritis, Am. J. M. Sc. **208**: 708-717 (Dec.) 1944.

261. Frugone, J. E.; Thomsen, P., and Luco, J. V.: Synaptic Transmission of Muscles in Arthritis, Proc. Soc. Exper. Biol. & Med. **59**:226-229 (June) 1945.

mission was different in arthritis. The atrophic muscles were also more resistant to curare. Neostigmine methylsulfate produced more depression and less potentiation in arthritic muscles. The synaptic behavior of arthritic muscle was similar to the behavior of tenotomized, immobilized and fatigued muscles.

Lövgren [262] studied 99 cases of chronic polyarthritis and found decreased cevitamic acid and serum iron in rheumatoid arthritis. In osteoarthritis there was an increased cevitamic acid, which was found greatly increased in allergic arthritis. Under treatment the values returned to normal. A fatty liver was found in 42 per cent, amyloidosis of the liver in 8 per cent and cirrhosis in 10.7 per cent. Adenylpyrophosphoric acid was used in dosage of 30 to 45 mg. daily intravenously and intramuscularly in 144 patients. Of these, 95 improved.

Tabetic arthropathies may change greatly in two months.[263] The destruction of the afferent nerves renders the joints incapable of compensating for injury. Charcot's joint is found in 4 to 10 per cent of tabes and in 25 per cent of syringomyelia. The early treatment is support and rest until acute symptoms pass. Fusion of the joints is no longer advocated. A corset is used for the spine. In the hip, walking with two crutches or a low subtrochanteric osteotomy is advised. A caliper with knee pad is best for the knee. This is later changed to a lock joint with an elastic support for the knee and a cane. An ankle brace and foot pads are used for the ankle and foot. Pressure must be avoided, or trophic ulcers may result. Fractures heal as in normal bones. Amputation is rarely necessary.

Frankel and his associates [264] produced Staphylococcus aureus infection in the knee joints of rabbits; twenty-four to forty-eight hours later penicillin (amount not stated) and propamidine (4,4'-diamidinodiphenoxypropane) 1 per cent were injected into the knee. In all animals sterile joints developed with little or no damage. Propamidine was highly toxic for all the animals.

262. Lövgren, O.: Intermediary Metabolism in Chronic Polyarthritis: Therapeutic Deductions with Special Consideration of Adenylpyrophosphoric Acid, Acta med. Scandinav., 1945, supp. 163, pp. 1-150.

263. Key, J. A.: Treatment of Tabetic Arthropathies, Urol. & Cutan. Rev. **49**:161-166 (March) 1945.

264. Frankel, C. J.; Lee, R. W., and Houlihan, R. B.: Experimental Use of Penicillin and Propamidine in Acute Purulent Arthritis, Exper. Med. & Surg. **2**:290-297 (Nov.) 1944.